NASA CONTRACTOR REPORT

NASA CR-227

STUDIES OF SONIC BOOM INDUCED DAMAGE

Prepared under Contract No. NAS 1-1166 *by*
CLARK, BUHR & NEXSEN
Norfolk, Va.

for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • MAY 1965

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SECTION I. FOREWORD

In August of 1961 the firm of Clark, Buhr and Nexsen, Architects and Engineers, under contract with the National Aeronautics and Space Administration, Langley Research Center, began preliminary conferences with representatives of National Aeronautics and Space Administration, the U. S. Air Force, the Federal Aviation Agency, and representatives of the National Opinion Research Center (University of Chicago) also under contract with National Aeronautics and Space Administration to establish criteria for structural investigation of sonic boom damage. Also, representatives of Clark, Buhr and Nexsen researched existing data compiled as a result of sonic boom damage complaints against the Government.

The St. Louis, Missouri area was selected as the site for test flights of supersonic aircraft and field investigations of damage to structures by the sonic boom overpressures. Test flights were flown during the periods of November 6 through 12, 1961 and January 3 through 6, 1962. Representatives of Clark, Buhr and Nexsen were in the target area during the periods of the test flights. An architect, a structural engineer, and a mechanical engineer comprised the investigating team.

The phase of the overall test program that is covered by this report constitutes research of typical sonic boom claims, investigation of alleged damage to structures caused by the specific test flights, compilation and organization of field data into a comprehensive report.

SECTION II. FIELD INVESTIGATIONS

During the two test periods of November 6 through 12, 1961 and January 3 through 6, 1962, a total of seventeen supersonic flights were accomplished in a predesignated flight corridor by test aircraft scheduled by National Aeronautics and Space Administration. The aircraft participating were of two types; one was a B-58 supersonic bomber, and the other was a F-106 fighter aircraft, both supplied and piloted by the U. S. Air Force.

Following is a log of official test flights indicating date, time of day, type of aircraft, altitude, and speed. These test flights did not vary from the predetermined flight corridor by more than one mile.

LOG OF SONIC BOOM TEST FLIGHTS

Date	Time of Day CST	Aircraft Type	Altitude Ft.	Mach No.
6 Nov 1961	2304	F-106	41,000	2.0
6 Nov 1961	2316	F-106	41,000	2.0
8 Nov 1961	1105	B-58	41,000	1.5
8 Nov 1961	1128	B-58	41,000	1.5
9 Nov 1961	1258	F-106	41,000	2.0
9 Nov 1961	1313	F-106	41,000	2.0
10 Nov 1961	1759	F-106	41,000	2.0
11 Nov 1961	0027	B-58	41,000	1.5
11 Nov 1961	0050	B-58	41,000	1.5
12 Nov 1961	0501	F-106	41,000	2.0
12 Nov 1961	0518	F-106	41,000	2.0
12 Nov 1961	1016	B-58	41,000	1.5
12 Nov 1961	1041	B-58	41,000	1.5
3 Jan 1962	2207	B-58	35,000	1.5
3 Jan 1962	2231	B-58	35,000	1.5
6 Jan 1962	2209	B-58	31,000	1.5
6 Jan 1962	2228	B-58	31,000	1.5

St. Louis had been subjected to frequent sonic boom occurrences during the four months preceding and simultaneously with the test flights. Prior to the scheduled test flights, the Air Force policy had been followed, and the populace was indoctrinated as to cause, purpose, and responsibility related to sonic booms. Newspaper, radio, television, and personal appearances by P.I.O. personnel were used to acquaint the residents with the phenomenon of sonic booms and that damage

to buildings can be expected. They were advised of whom to call if damage was sustained and that the Air Force would accept responsibility for sonic boom caused damage.

The test flights were held confidential; however, the area had been thoroughly saturated by sonic boom occurrences and was familiar with damage reporting procedures.

The Judge Advocate General's office at Scott Air Force Base handled sonic boom complaints for the test flights. Scott Air Force Base is located in Illinois approximately 40 miles from St. Louis. Telephoned complaints entailed a long distance phone call. Personnel at the base recorded the complaints on previously prepared forms. A copy of the form is appended to this Section as Exhibit No. 1.

An investigation team, comprised of an Air Force legal officer, a photographer, and an architect or engineer, was relayed the complaint information from the Base so as to arrive at the scene of reported damage as soon as possible. Most complaints, however, were investigated the day following due to the time of the night flights and time lag of complaints.

Clark, Buhr and Nexsen investigation teams made a total of 84 investigations of reported damage from sonic booms specifically related to the scheduled flights. Investigation report forms were used by the architect or engineer to obtain pertinent data on the structure. The form, supplemented by photographs of the reported damage, were used as a basis of analysis. A copy of the form is appended to this Section as Exhibit No. 2.

EXHIBIT NO. 1

1. NAME
2. STREET
3. CITY
4. STATE
5. HOME PHONE
6. BUSINESS PHONE
7. COMPLAINT
- ☐ ANNOYANCE
- ☐ PERSONAL INJURY
- PROPERTY DAMAGE
- ☐ GLASS
- ☐ PLASTER
- ☐ FURNISHINGS
- ☐ STRUCTURAL
- ☐ OTHER

8. DETAILS OF COMPLAINT
9. BEST DAYS AND HOURS FOR INSP
POSTED
10. SONIC REPORT NR
11. OCCURRED *(Date and Hour)*
12. REPORTED *(Date and Hour)*
13. BY ☐ PHONE ☐ LETTER
TO:

SCOTT AFB FORM JUL 81 0-170 TEST SONIC BOOM REPORT

FRONT

ACTION DATE

14. REFERRED TO
15. INITIAL CONTACT:
- FORM LETTER
- SPECIAL LETTER
- TELEPHONE
- PERSONAL VISIT

16. FORM 95 SENT
17. FORM 95 REC'D AMOUNT $
18A. ESTIMATE REC'D AMOUNT $
18B. ESTIMATE REC'D AMOUNT $
19. REPAIR BILL REC'D AMOUNT $
20. INSPECTED BY
21. RECOMMEND PAY $ _____ COMPROMISE $ _____ DENY _____
22. COMMENT
23. CLOSED (Date) (By)

BACK

EXHIBIT NO. 2

SONIC BOOM DAMAGE INVESTIGATION REPORT

1. NAME: _____

2. ADDRESS: _____

3. DATE AND TIME OF DAMAGE: _____

4. TYPE OF CONSTRUCTION:

- ☐ Frame
- ☐ Brick Veneer
- ☐ Block
- ☐ Other - (describe)

_____

5. NUMBER OF STORIES:

- ☐ One
- ☐ Two
- ☐ Three
- ☐ Other

6. BASEMENT: ☐ Yes ☐ No

7. TYPE OF USAGE:

- ☐ Residential
- ☐ Garage or Utility
- ☐ Commercial - (describe)

_____

8. AGE OF STRUCTURE: _____ yrs.

9. CONDITION OF STRUCTURE: _____

_____

_____

10. EVIDENCE OF SETTLEMENT: _____

_____

11. TYPE OF DAMAGE:

- ☐ Personal Property
- ☐ Glass
- ☐ Plaster
- ☐ Structural
- ☐ Other

12. FULLY DESCRIBE DAMAGE: _____

_____

_____

_____

_____

SECTION III. COMPILATION OF DATA

The data acquired during the field investigations has been analyzed, compiled, and presented on the group of bar graphs that follow. The location and credibility of reported damage have been plotted on area maps for each flight and on a composite map which follow the bar graphs. No credibility has been established for investigations by any source other than by National Aeronautics and Space Administration sponsored investigations.

Figure No. 1 and No. 1A reflects the different types of construction of the 84 structures investigated. The following list shows the breakdown:

	No. Investigated	% of Total
Frame	25	29.8
Brick Veneer	26	31.0
Brick Wall	24	28.6
Block	5	5.9
Other	4	4.7

Figure No. 2 and No. 2A reflects the number of stories to structures investigated. The following list shows the breakdown:

	No. Investigated	% of Total
One Story	34	40.5
Two Story	43	51.2
Three Story	6	7.2
Other	1	1.1

Figure No. 3 and No. 3A reflects the sub-floor conditions of structures investigated. The following list shows the breakdown:

	No. Investigated	% of Total
With Basement	50	59.5
Without Basement	21	25.0
Not available	13	15.5

Figure No. 4 and No. 4A reflects the type of usage of structures investigated.

	No. Investigated	% of Total
Residential	68	81.0

(Cont'd)	No. Investigated	% of Total
Resid.-Comm.	8	9.5
Commercial	7	8.9
Garage-Utility	1	1.1

Figure No. 5 and No. 5A reflects the age of structures investigated.

	No. Investigated	% of Total
1-5 years	17	20.2
6-10 years	7	8.3
11-20 years	7	8.3
21-40 years	19	22.6
41-60 years	19	22.6
60-over	15	18.0

Figure No. 6 and No. 6A reflects the interior condition of structures investigated.

	No. Investigated	% of Total
Good	26	31.0
Fair	32	38.0
Poor	26	31.0

Figure No. 7 and No. 7A reflects the evidence of settlement in structures investigated.

	No. Investigated	% of Total
Settlement	49	58.4
No Settlement	18	21.4
Not Available	17	20.2

Figure No. 8, 8A, 9, and 9A reflect the type of damage reported to structures investigated.

	Number Investigated	% of Total	Valid		Doubtful	
			No.	%	No.	%
Damage structural	5	6.0	1	20.0	4	80.0
Plaster	34	40.3	6	17.5	28	82.5
Glass - 1 pane	16	19.0	5	31.2	11	68.8
Glass - 2 pane	8	9.5	4	50.0	4	50.0
Glass - 3 or more panes	1	1.2	1	100.0	0	0.0

(Cont'd)	Number Investigated	% of Total	Valid No.	Valid %	Doubtful No.	Doubtful %
Cracked tiles & fixtures	4	4.8	2	50.0	2	50.0
Broken due to fall	4	4.8	4	100.0	0	0.0
Broken objects	1	1.2	1	100.0	0	0.0
Appliances	4	4.8	0	0.0	4	100.0
Plaster and glass	6	9.8	3	50.0	3	50.0
Plaster and furnishings	1	1.2	0	0.0	1	100.0

Figure No. 10 and 10A reflects the credibility of complaints investigated.

	No. Investigated	% of Total
Valid	28	33.3
Doubtful	56	66.6

In an effort to keep the statistics as accurate, simple, and easy to interpret as possible, only valid and doubtful categories are used. Possibly valid cases are considered valid.

To clarify the phraseology used to describe the opinions of the investigators, the list and intended meanings of words and phrases used to describe opinions follows:

Valid. In the opinions of the investigators the damage was probably due to, or was triggered by sonic boom overpressures.

Possibly Valid. In the opinions of the investigators the damage may or may not have been caused by sonic boom overpressures. The damage in this case appeared recent and the structure appeared sound and well maintained. While there was no apparent cause for the damage, it was of the type that could be caused by a sonic boom.

Doubtful. In the opinions of the investigators the damage was not due to sonic boom overpressures. In this case a definite cause other than sonic boom was established for the damage claimed, or the damage was not of a type expected to be caused by a sonic boom.

Cognizance should be taken of the fact that the investigations revealed many situations that could not be accepted or denied without question. The judgment of the trained architect or engineer served as the only basis for decision in the possibly valid cases.

Each sonic boom test flight is plotted separately on a map along with the locations of each complaint received for that specific flight. (See figures 11 through 20). Symbols on the map indicate

the credibility, and if investigated by the National Aeronautics and Space Administration engineering investigation team or by the Air Force. The time of flight, type, altitude, and mach number of the aircraft, and flight path also are indicated on the map. A composite map, representing all damage complaints attributed to the 17 sonic boom test flights, is also included.

Since the sonic boom test flights were in most cases run in groups of two, one from 15 to 30 minutes after the first, plottings were made for both flights as one, instead of two separate flights. Persons reporting sonic boom damage to structures often referred to the time of occurrence as from 11:00 - 11:30; thus the reason for considering the two separate flights as one.

From observing the maps and the following table, it is seen that the area over which the aircraft flew and up to 4 miles from ground zero was highly industrial and commercial. These structures for the most part are sturdy but old. Many have been remodeled to come up to par with today's newer buildings, while others are old and in poor condition. In the latter group, any damage a sonic boom would cause is likely to go undetected due to numerous plaster and window cracks that already exist. Also persons notice damage in their own homes more so than they would in an industrial or commercial structure.

The area of greatest investigated complaints was from 4 to 6 miles from the flight track. This is a very old section, and the population density is large.

The zone 6 to 8 miles from the flight track was the next largest for investigated complaints.

In the 8 to 16 mile zones from the flight track the houses are spaced further apart, are newer, and are in a better state of repair than in the 0 to 8 mile zones.

The area to the right of the flight path, looking north on the composite map, has fewer investigated complaints than on the left of the flight path. This area is highly industrial with a low population density. The residences that do exist on the E. St. Louis side of the Mississippi River, from the flight track to 6 miles, are old and run down. Thus any damage caused by a sonic boom would often go unobserved due to numerous cracks, etc., that already existed in these structures.

COMPLAINTS PER ZONE

To the Left of Flight Path Looking North	Investigated by		
Miles from Flight Path	Air Force	CB&N Legitimate	CB&N Doubtful	Total
0 - 2	0	4	2	6
2 - 4	10	6	10	26
4 - 6	22	5	22	49
6 - 8	16	5	6	27
8 - 10	12	3	4	19
10 - 12	6	1	0	7
12 - 14	3	1	4	8
14 - 16	0	1	3	4
To the Right of Flight Path Looking North				
0 - 2	0	0	4	4
2 - 4	3	1	0	4
4 - 6	3	2	1	6
6 - 8	1	0	0	1
8 - 10	0	0	0	0

The maximum overpressure occurs at a distance of 0 to 2 miles from the flight track and, theoretically, should cause the largest amount of damage. The overpressure will generally decrease with distance from the flight track and will generally increase with lower aircraft altitude. Refer to following table of Sonic Boom Overpressures prepared by National Aeronautics and Space Administration.

It is interesting to note that the larger and heavier B-58 flying at the same altitude and at a lesser supersonic speed than the F-106, caused a greater overpressure from 0 to 10 miles from the flight track, and an overpressure approximately equal from 10 to 16 miles from the flight track.

The maps of the individual flights indicate that more damage investigations were made for the B-58, flying at 35,000 feet, than for any of the other flights.

SONIC BOOM OVERPRESSURES
ΔP_o, lbs/sq ft

Distance Miles	B-58 ΔP_o's, lbs/sq ft			F-106 ΔP_o's lbs/sq ft
	Altitude, Ft.			Altitude, Ft.
	41,000	36,000	31,000	41,000
0 - 2	1.8	2.2	2.6	1.3
2 - 4	1.8	2.0	2.3	1.3
4 - 6	1.7	1.9	2.0	1.2
6 - 8	1.4	1.6	1.7	1.1
8 - 10	1.0	1.1	1.3	0.8
10 - 12	0.6	0.8	1.0	0.6
12 - 14	0.3	0.5	0.6	0.4
14 - 16	0.2	0.3	0.4	0.3

NOTE:

The pressure indicated for a given zone will vary $\pm$ 0.3 lbs/sq ft.

FIGURE NO. 1

EXTERIOR CONSTRUCTION OF STRUCTURES INVESTIGATED

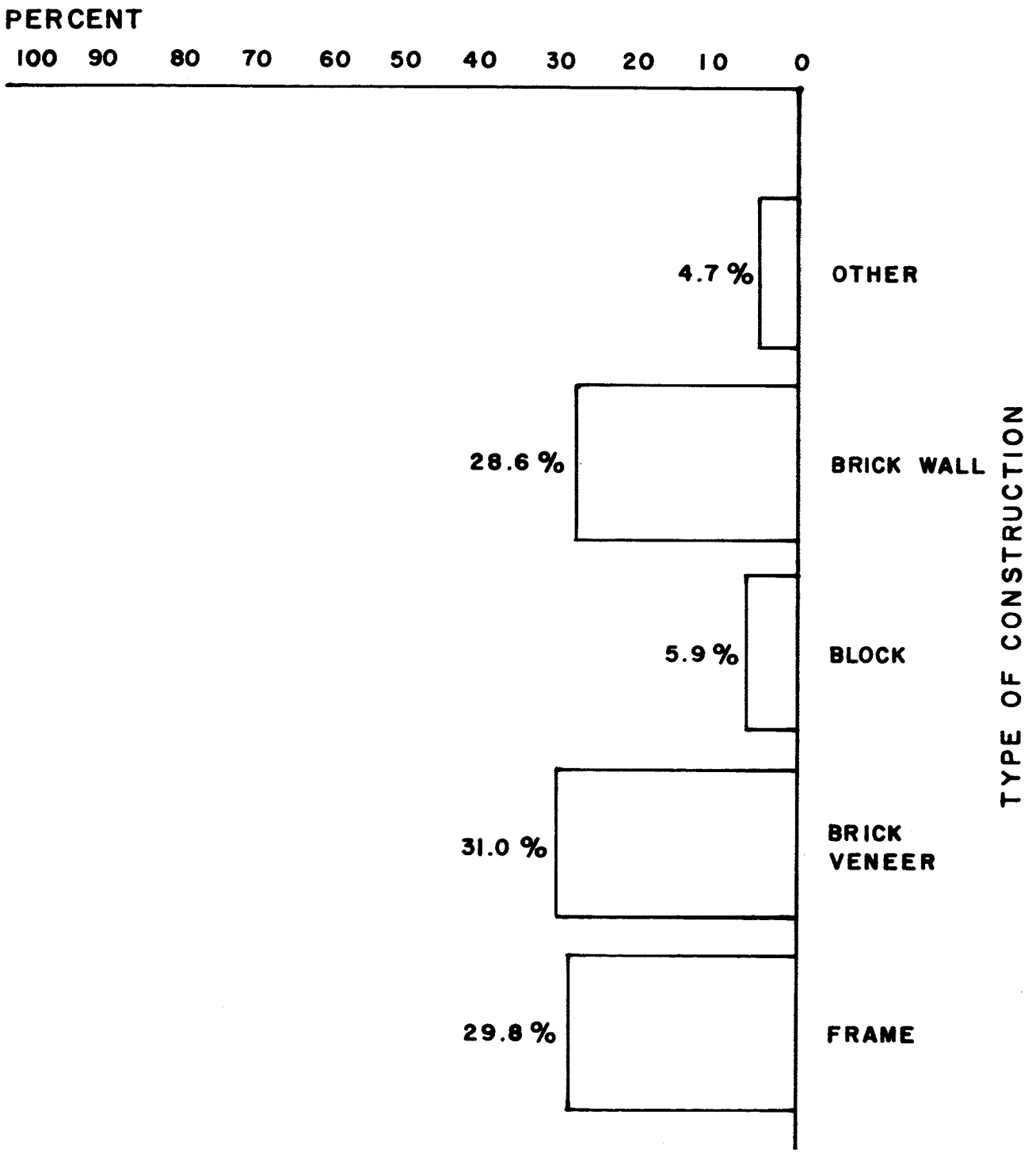


FIGURE NO. 1A

EXTERIOR CONSTRUCTION OF STRUCTURES INVESTIGATED

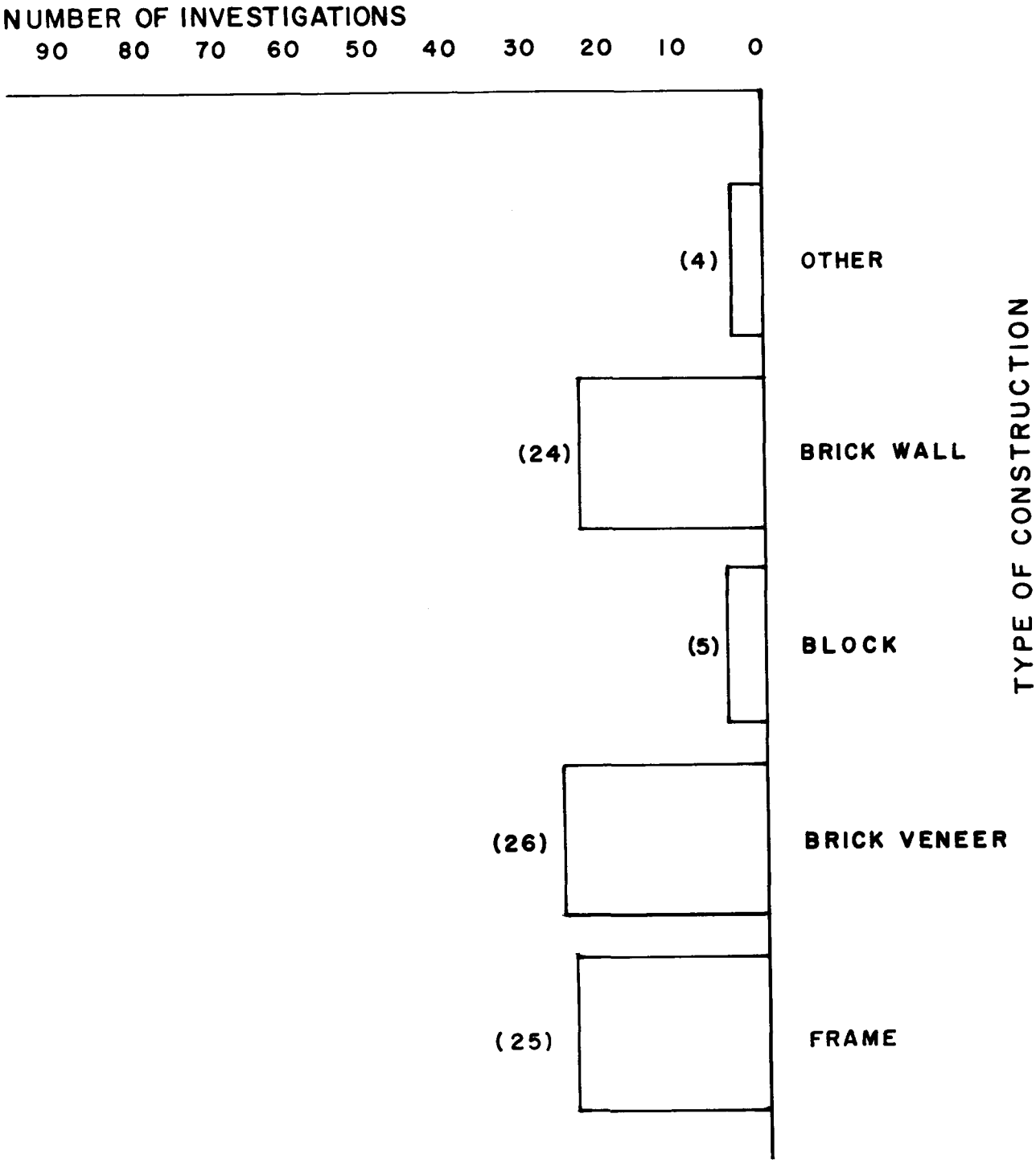


FIGURE NO. 2

NUMBER OF STORIES OF
STRUCTURES INVESTIGATED

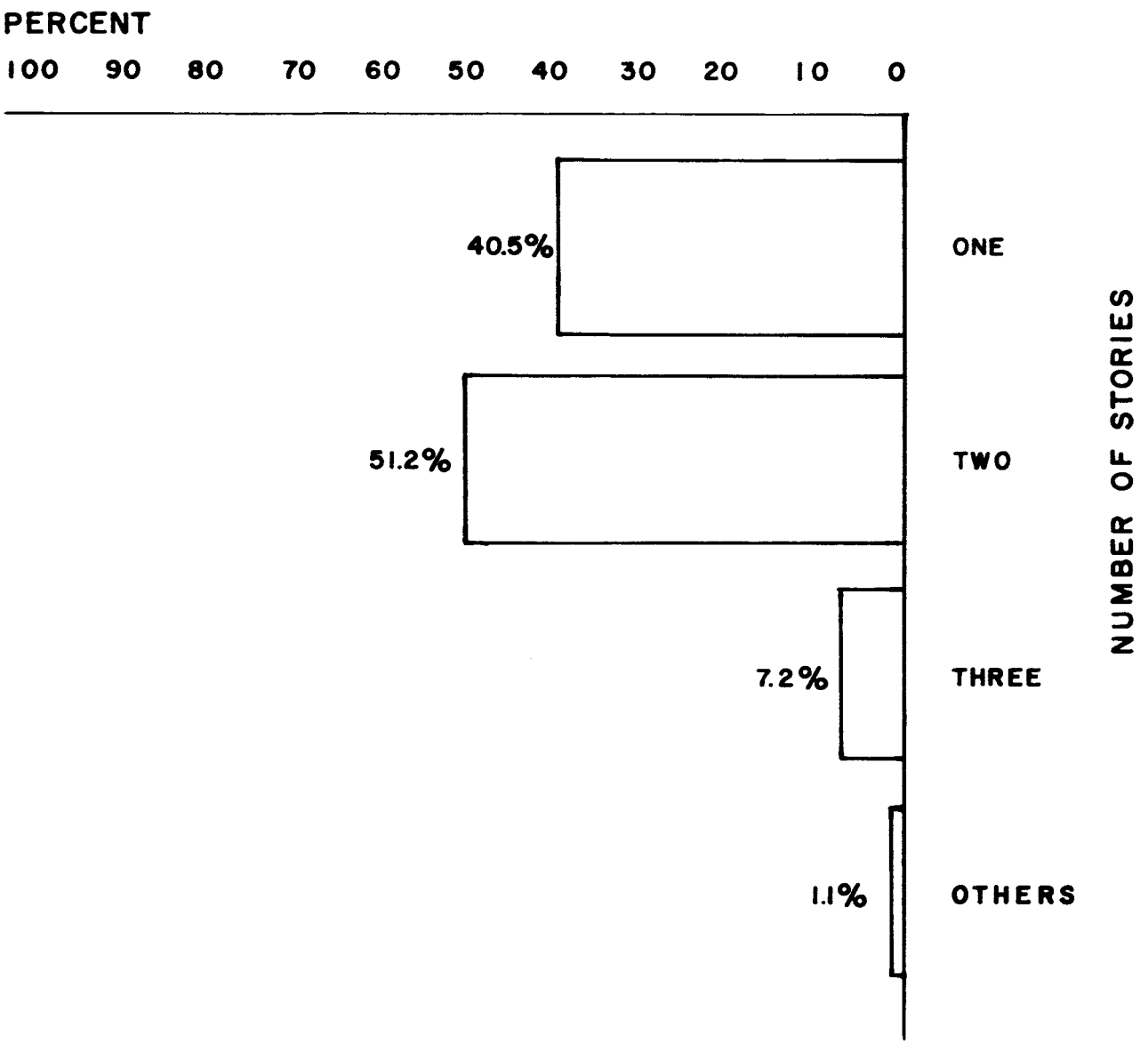


FIGURE NO. 2A

NUMBER OF STORIES OF STRUCTURES INVESTIGATED

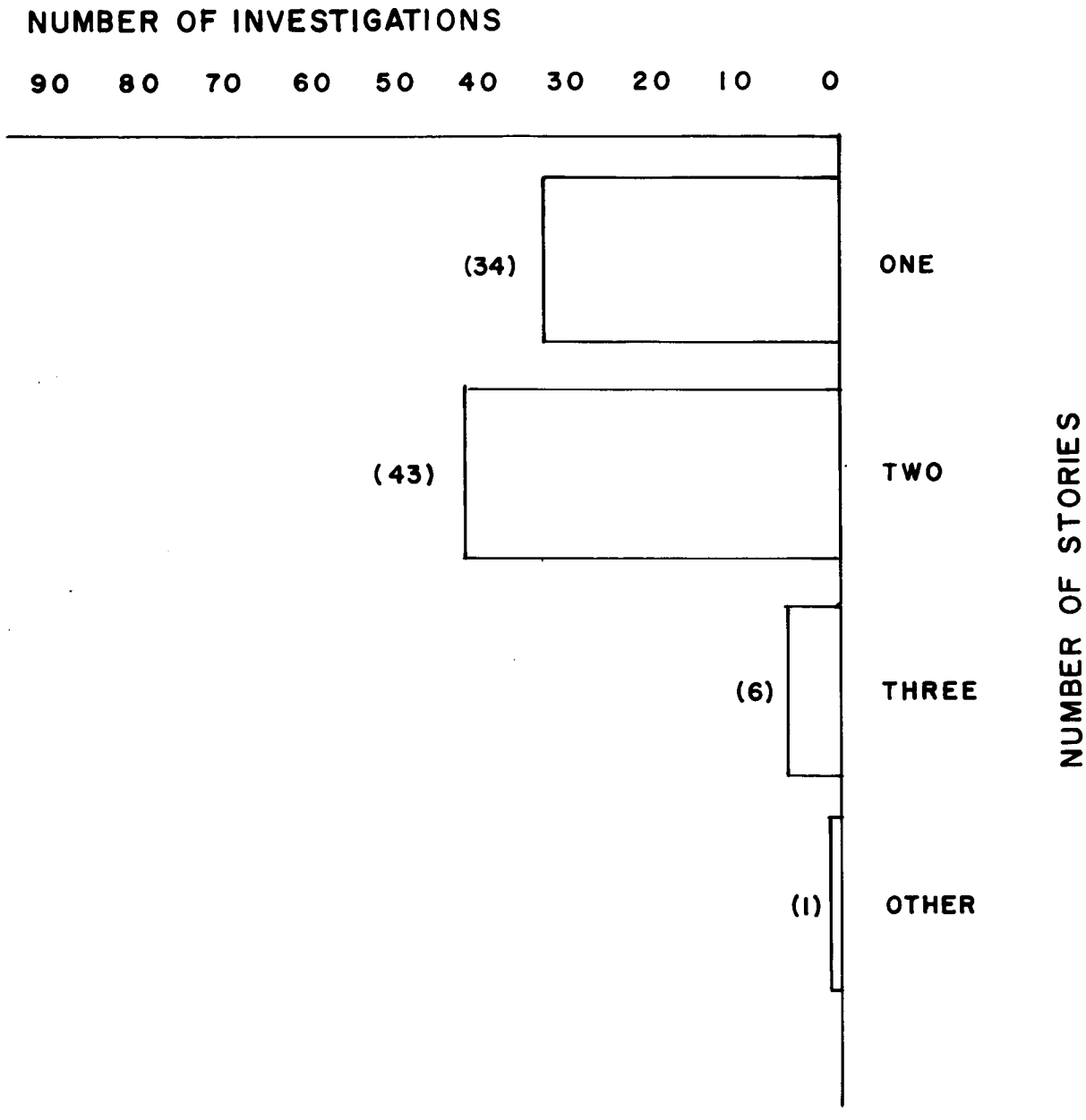


FIGURE NO. 3

SUB-FLOOR CONDITIONS OF STRUCTURES INVESTIGATED

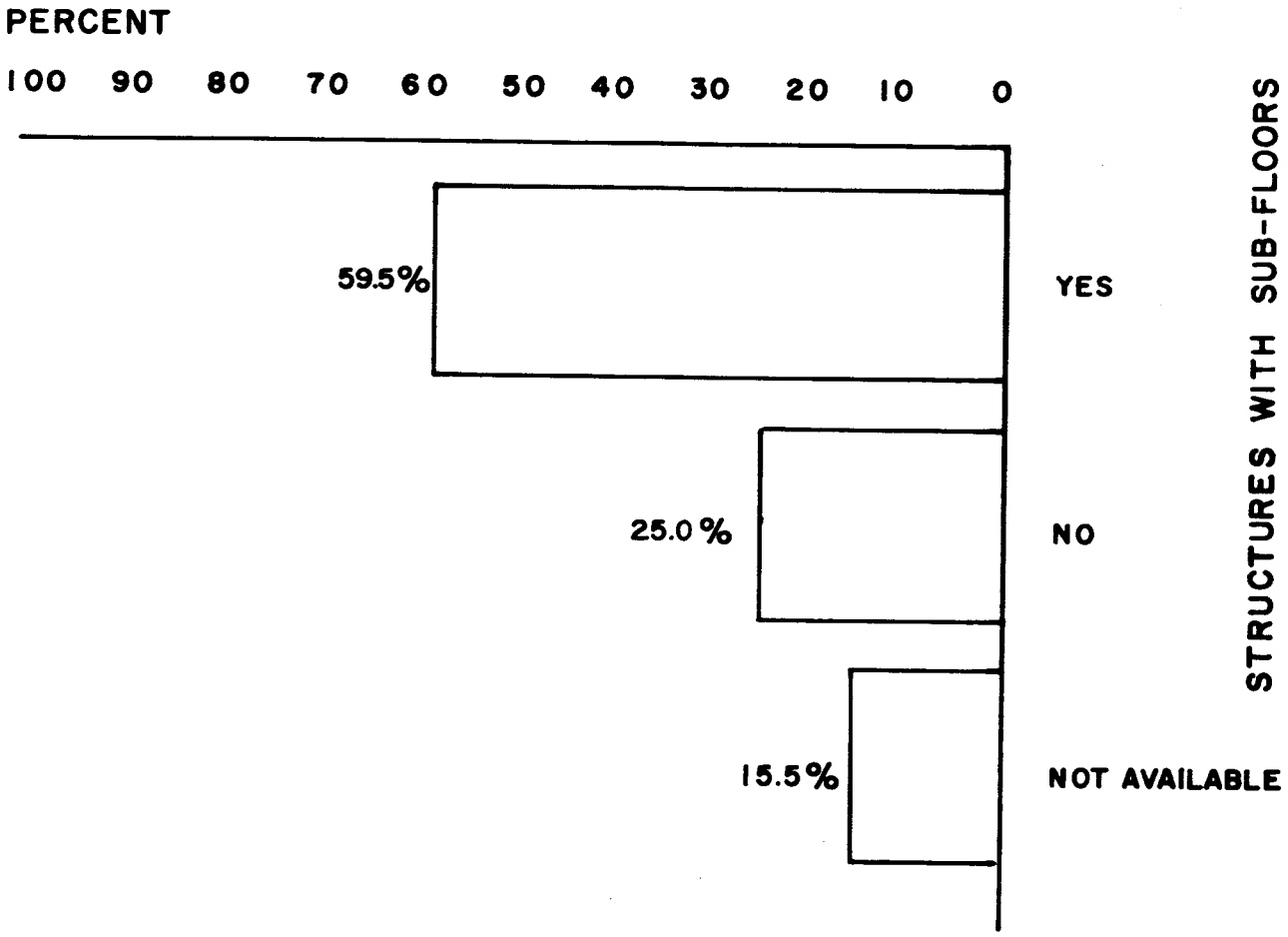


FIGURE NO. 3A

SUB-FLOOR CONDITIONS OF STRUCTURES INVESTIGATED

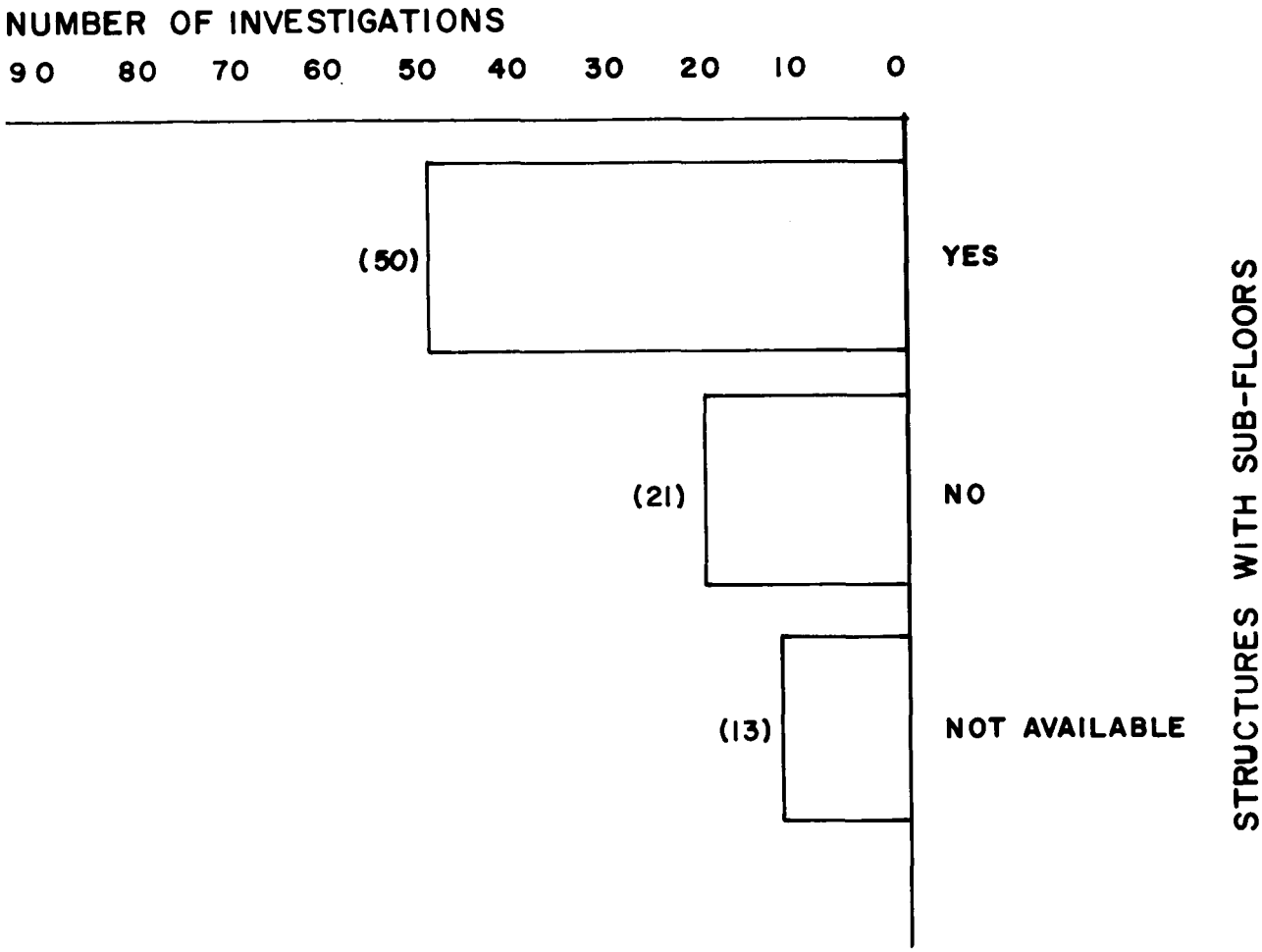


FIGURE NO. 4

TYPE OF USAGE OF STRUCTURES INVESTIGATED

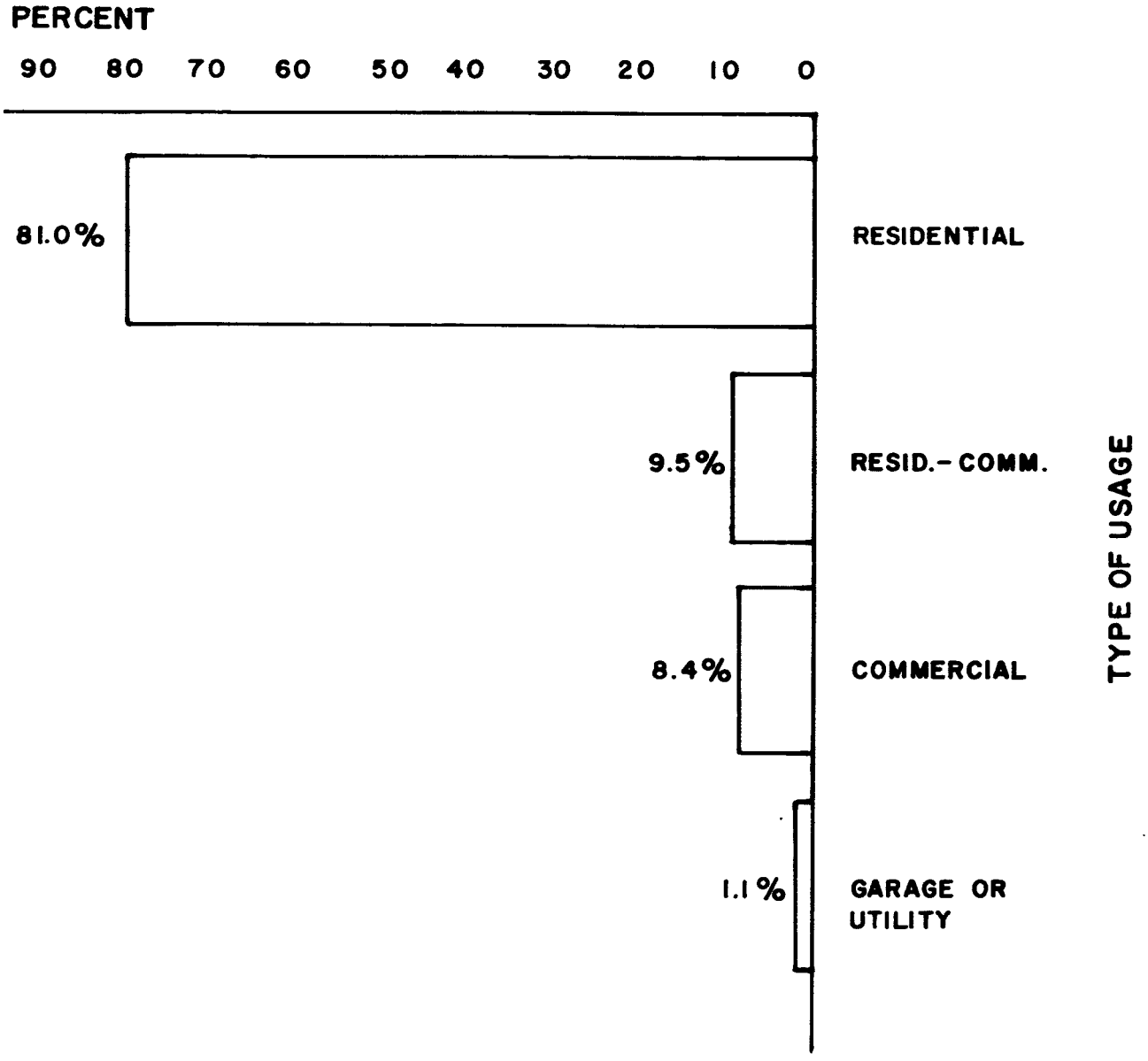


FIGURE NO. 4A

TYPES OF USAGE OF
STRUCTURES INVESTIGATED

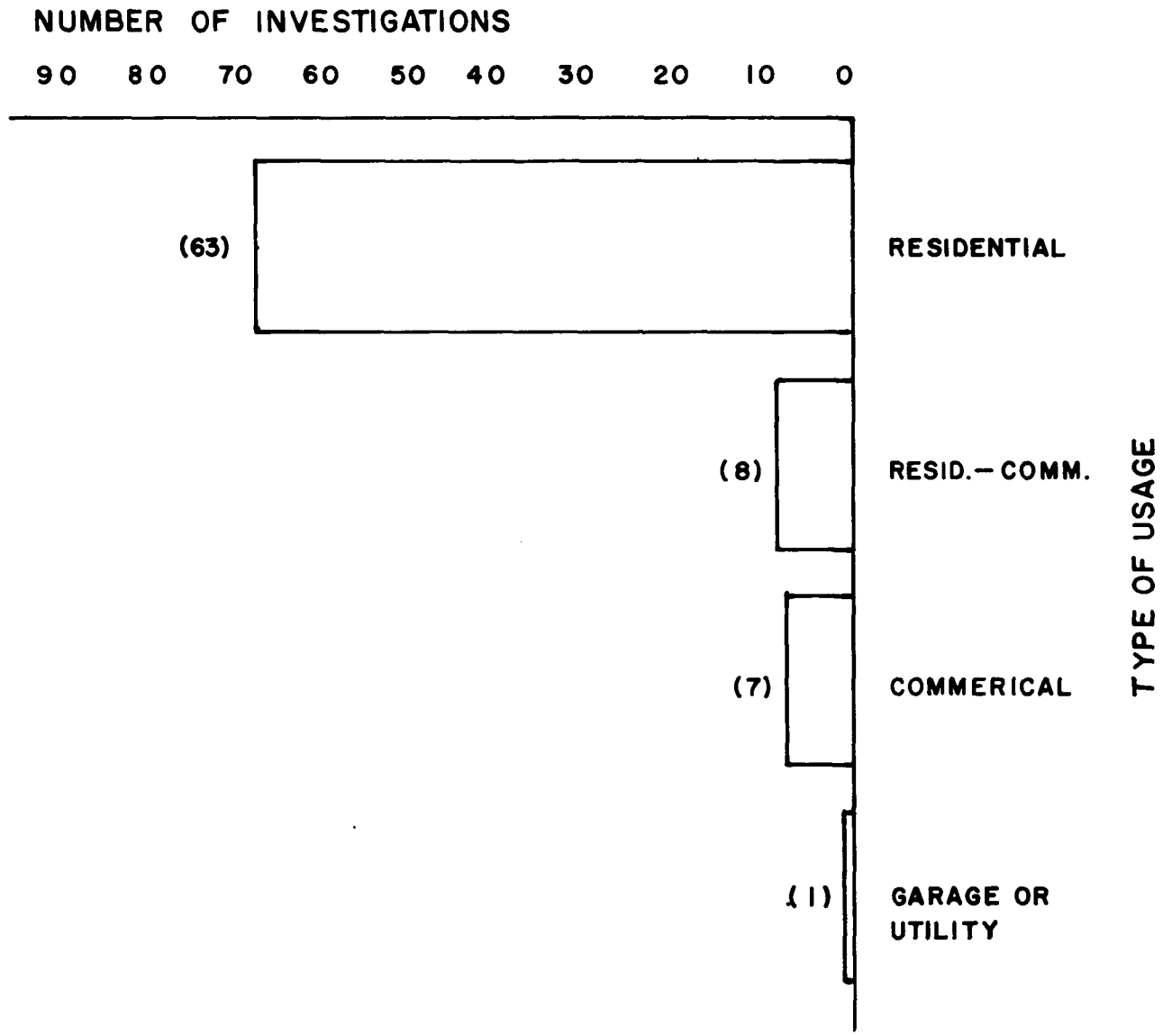


FIGURE NO. 5

AGE OF STRUCTURES
INVESTIGATED

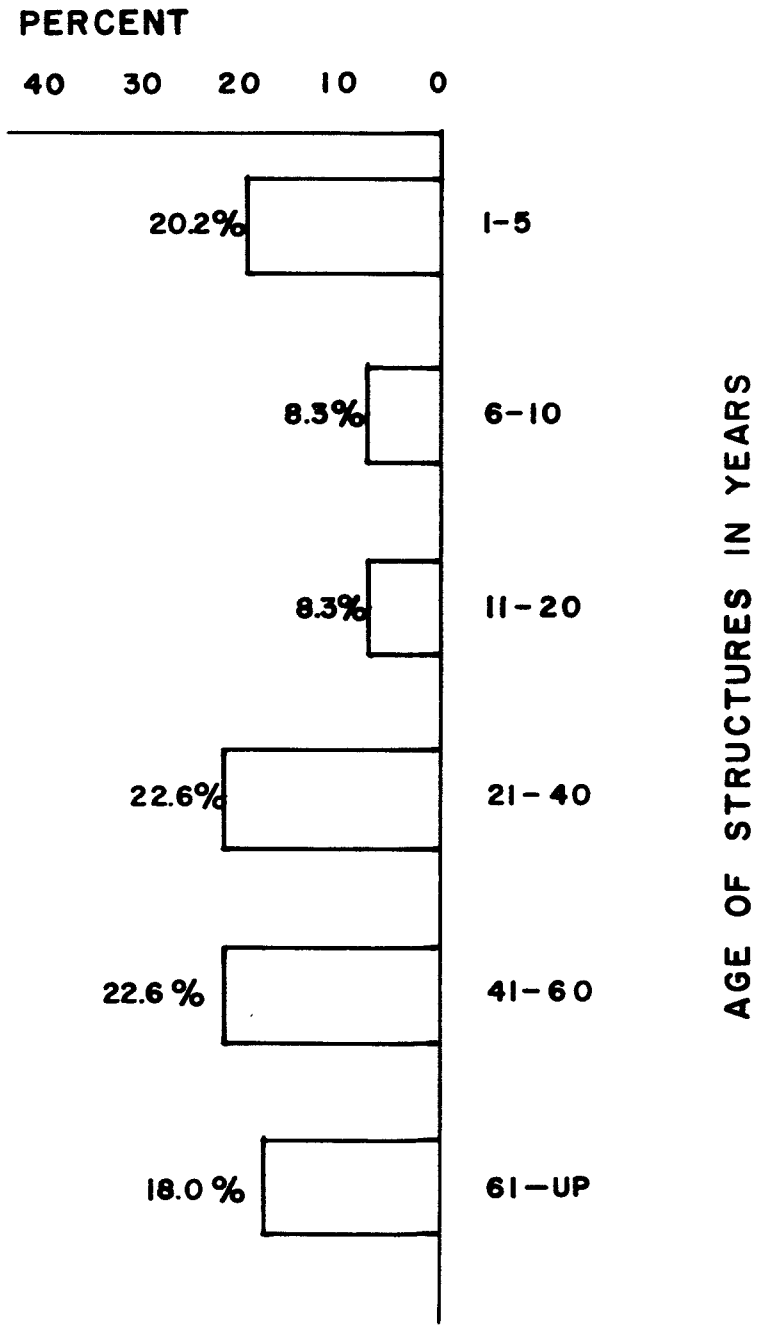


FIGURE NO. 5A

AGE OF STRUCTURES INVESTIGATED

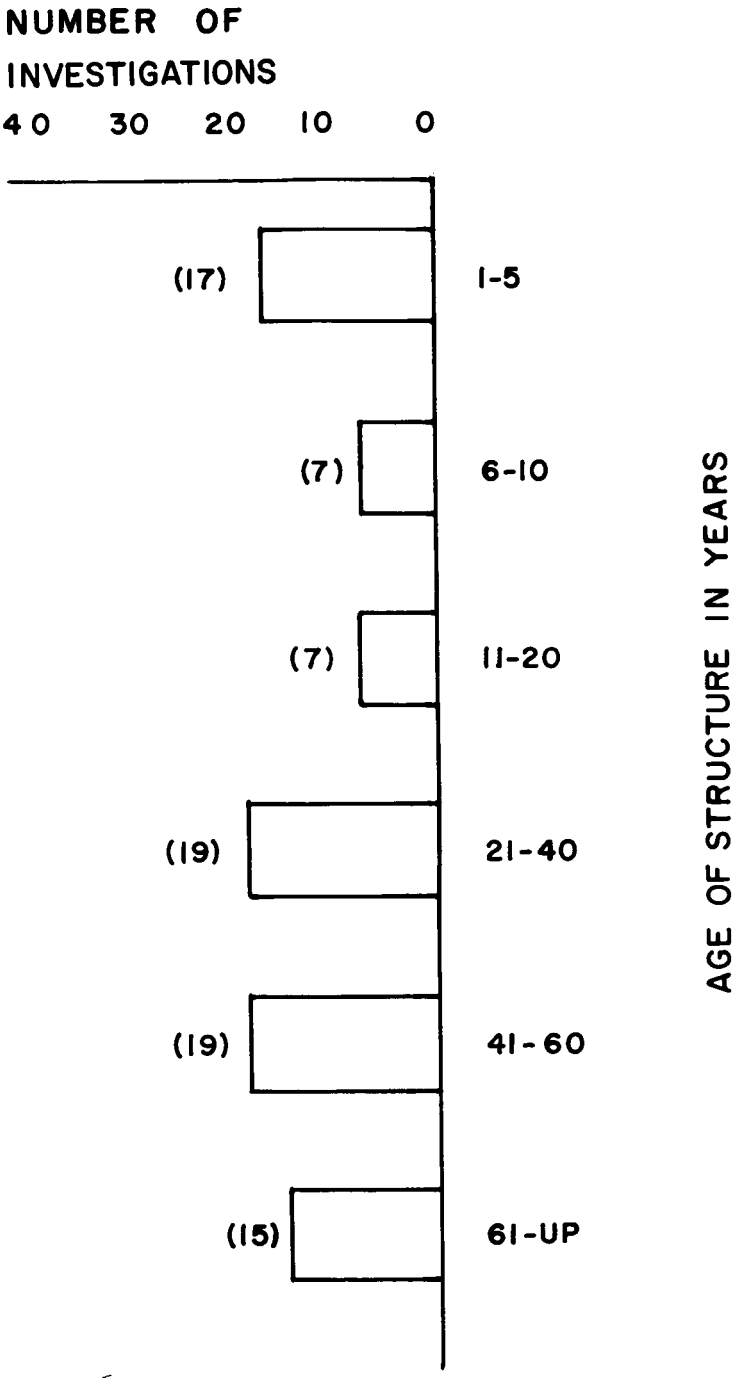


FIGURE NO. 6

INTERIOR CONDITION OF STRUCTURES INVESTIGATED

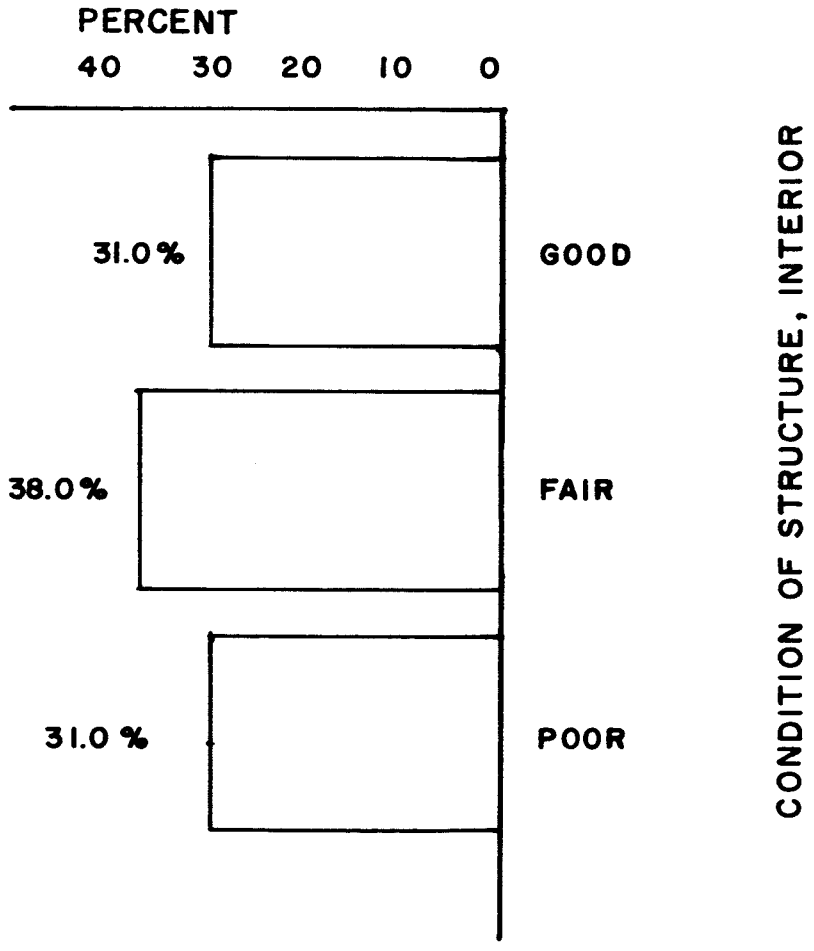


FIGURE NO. 6A

INTERIOR CONDITION OF STRUCTURES INVESTIGATED

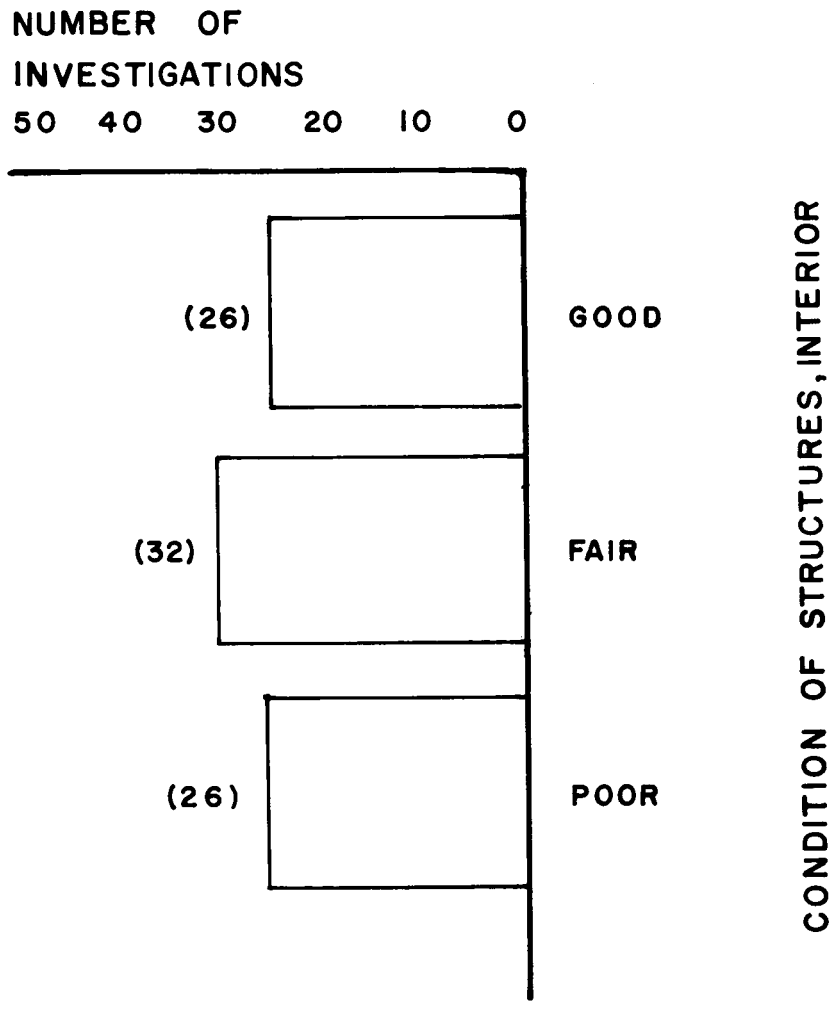


FIGURE NO. 7

EVIDENCE OF SETTLEMENT TO
STRUCTURES INVESTIGATED

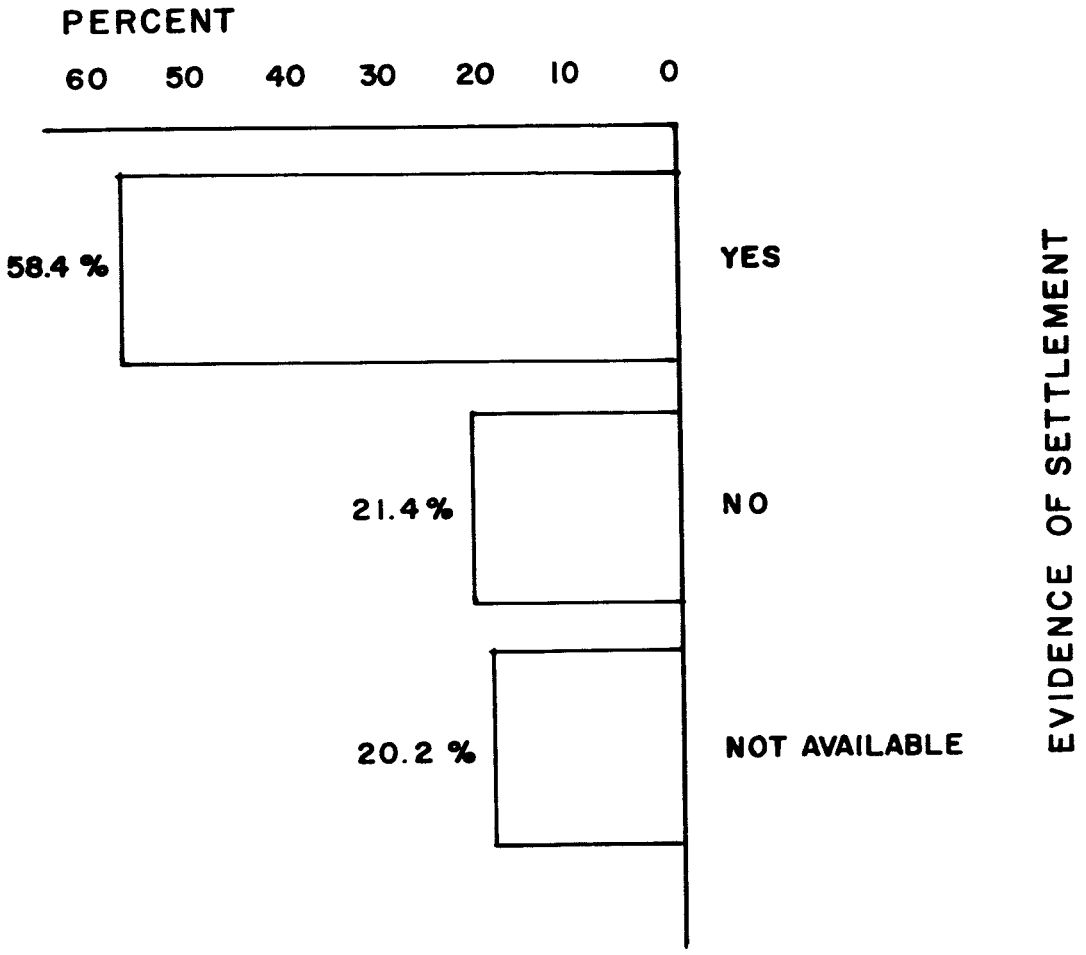


FIGURE NO. 7A

EVIDENCE OF SETTLEMENT TO STRUCTURES INVESTIGATED

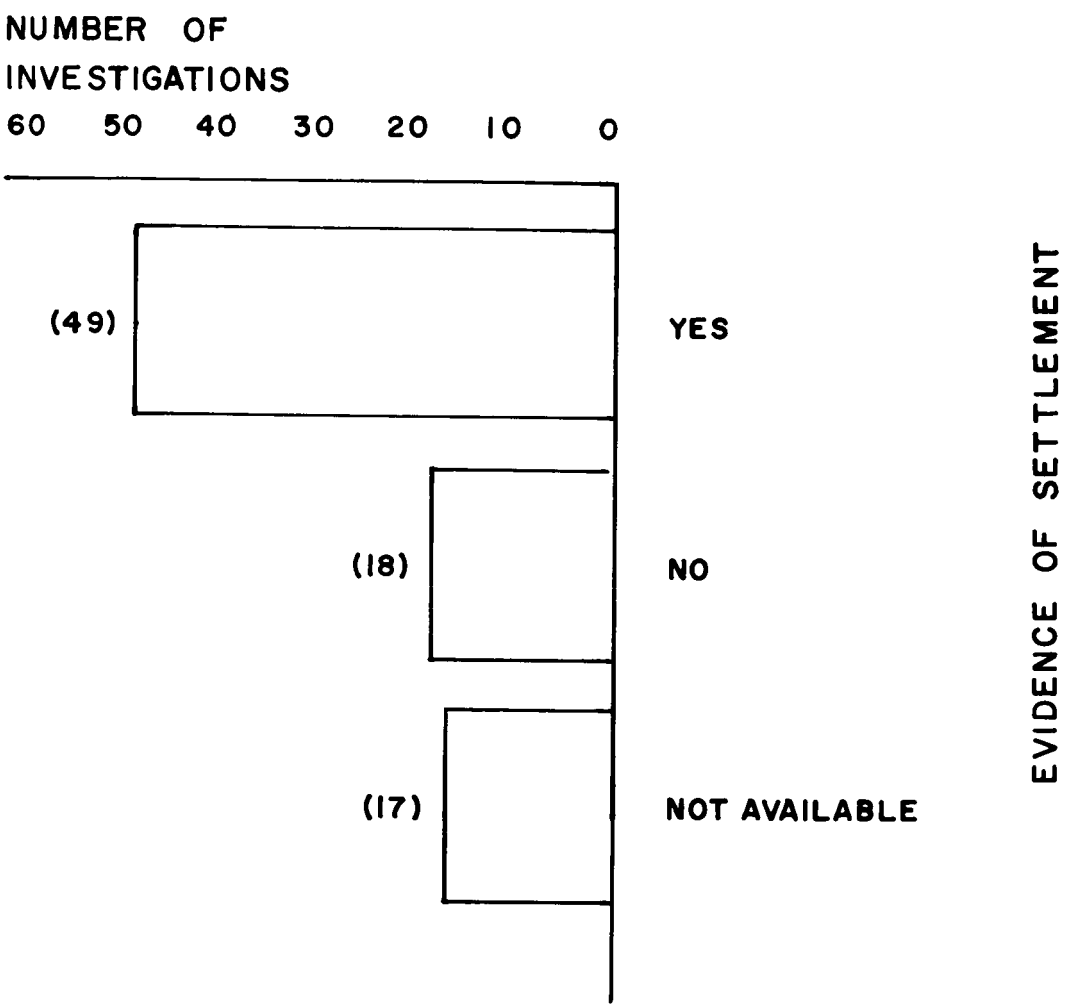


FIGURE NO. 8

TYPE OF DAMAGE TO STRUCTURES INVESTIGATED

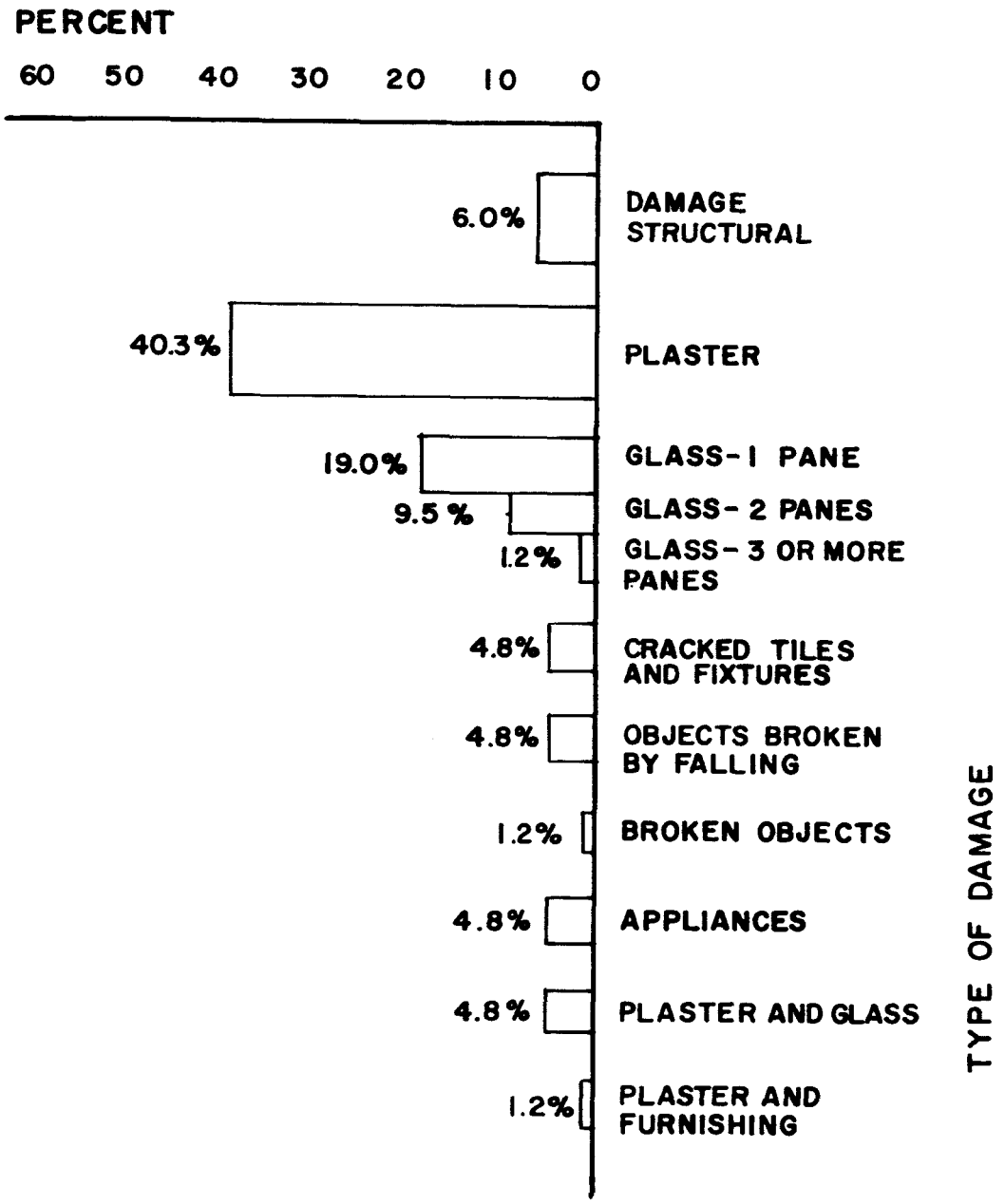


FIGURE NO. 8A

TYPE OF DAMAGE TO STRUCTURES INVESTIGATED

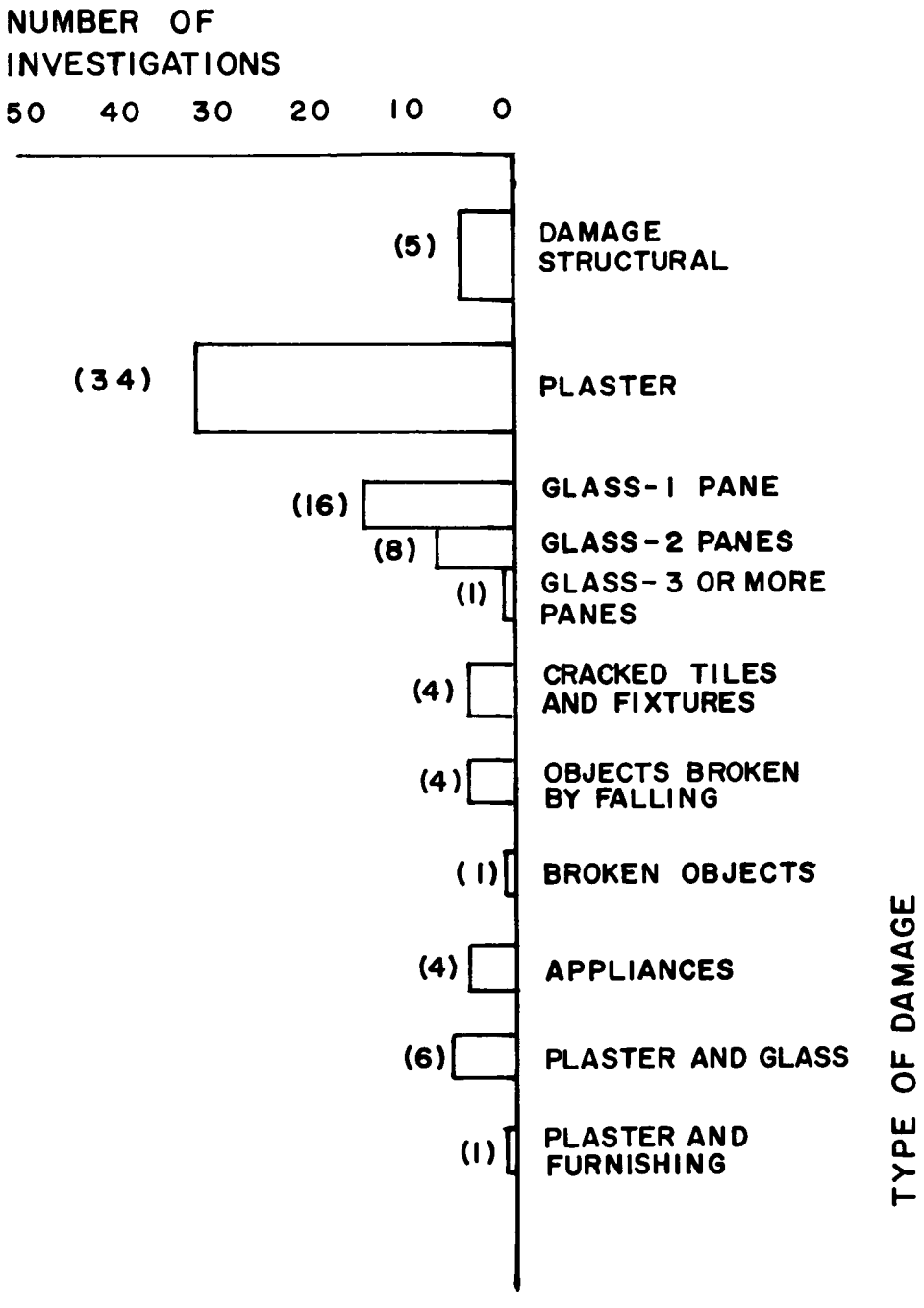


FIGURE NO. 9

CREDIBILITY AS TO TYPE OF DAMAGE TO STRUCTURES INVESTIGATED

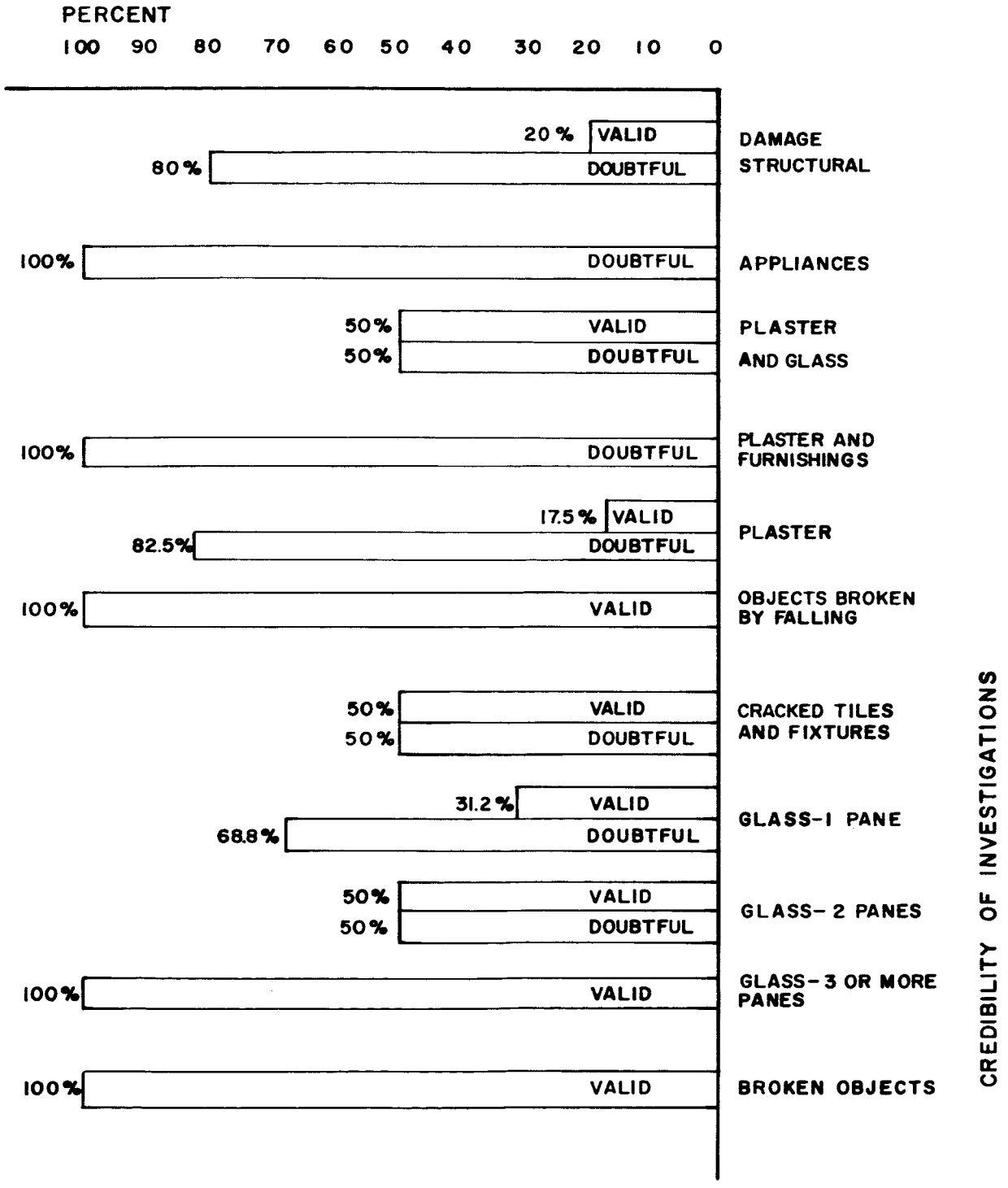


FIGURE NO. 9A

CREDIBILITY AS TO TYPE OF DAMAGE TO STRUCTURES INVESTIGATED

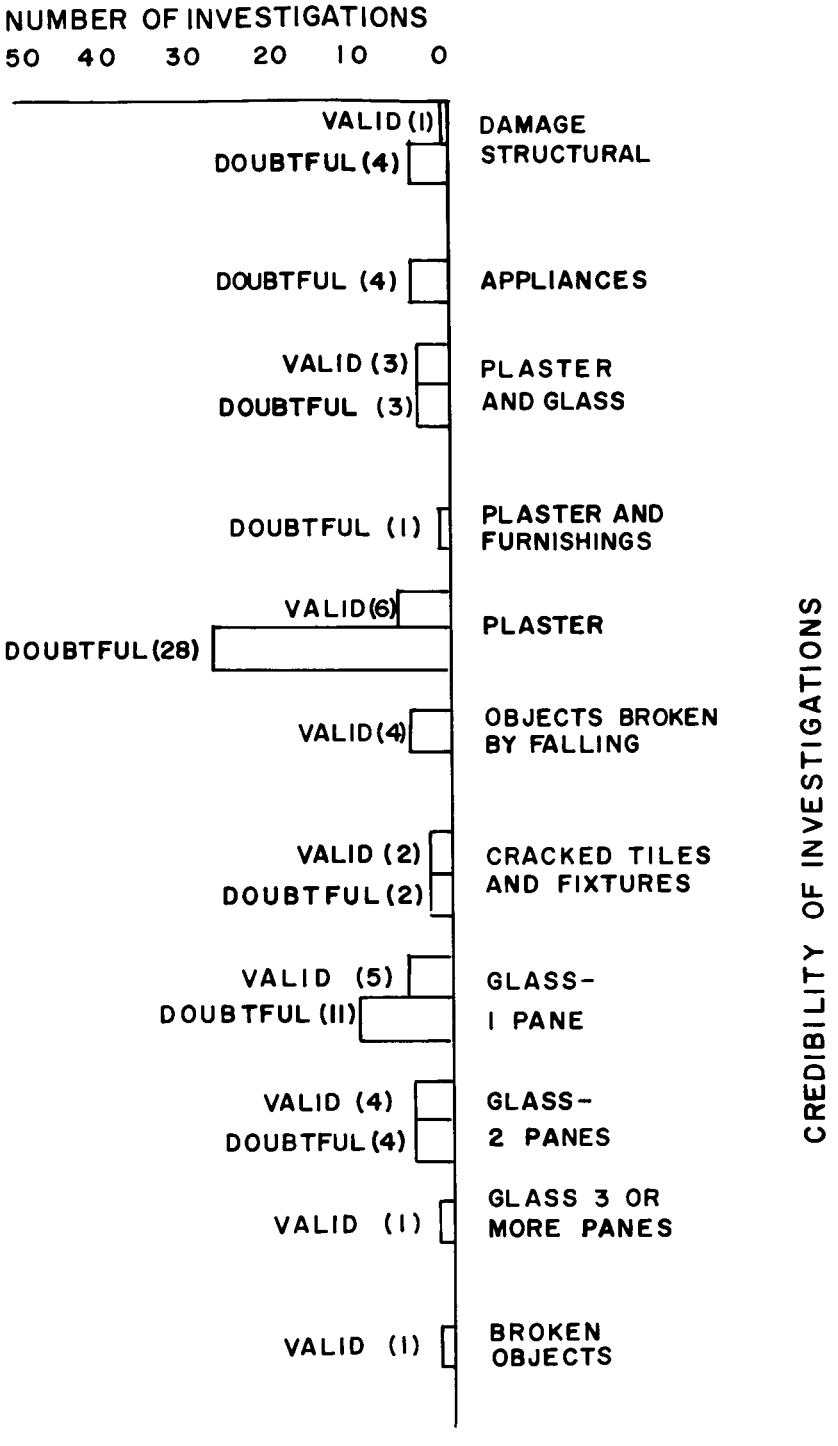


FIGURE NO. 10

CREDIBILITY OF COMPLAINTS INVESTIGATED

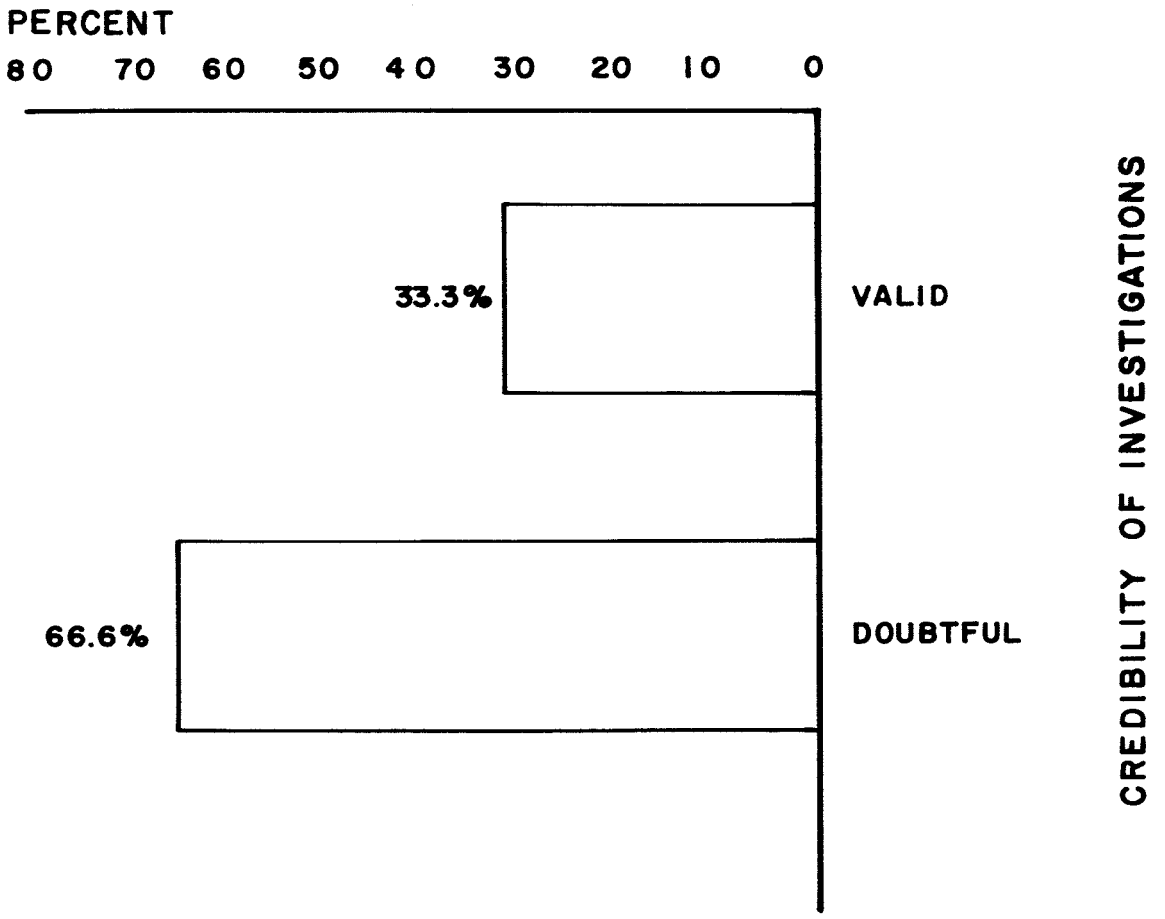


FIGURE NO. 10A

CREDIBILITY OF COMPLAINTS INVESTIGATED

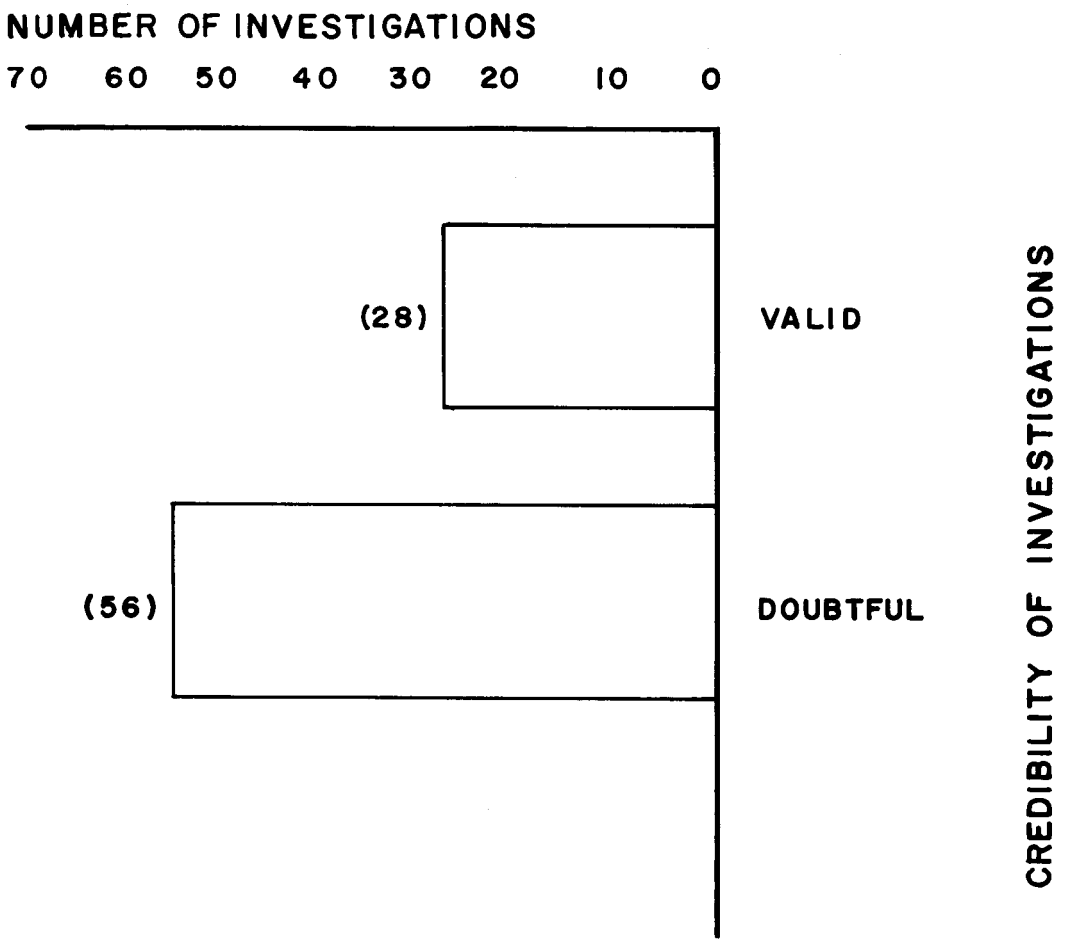
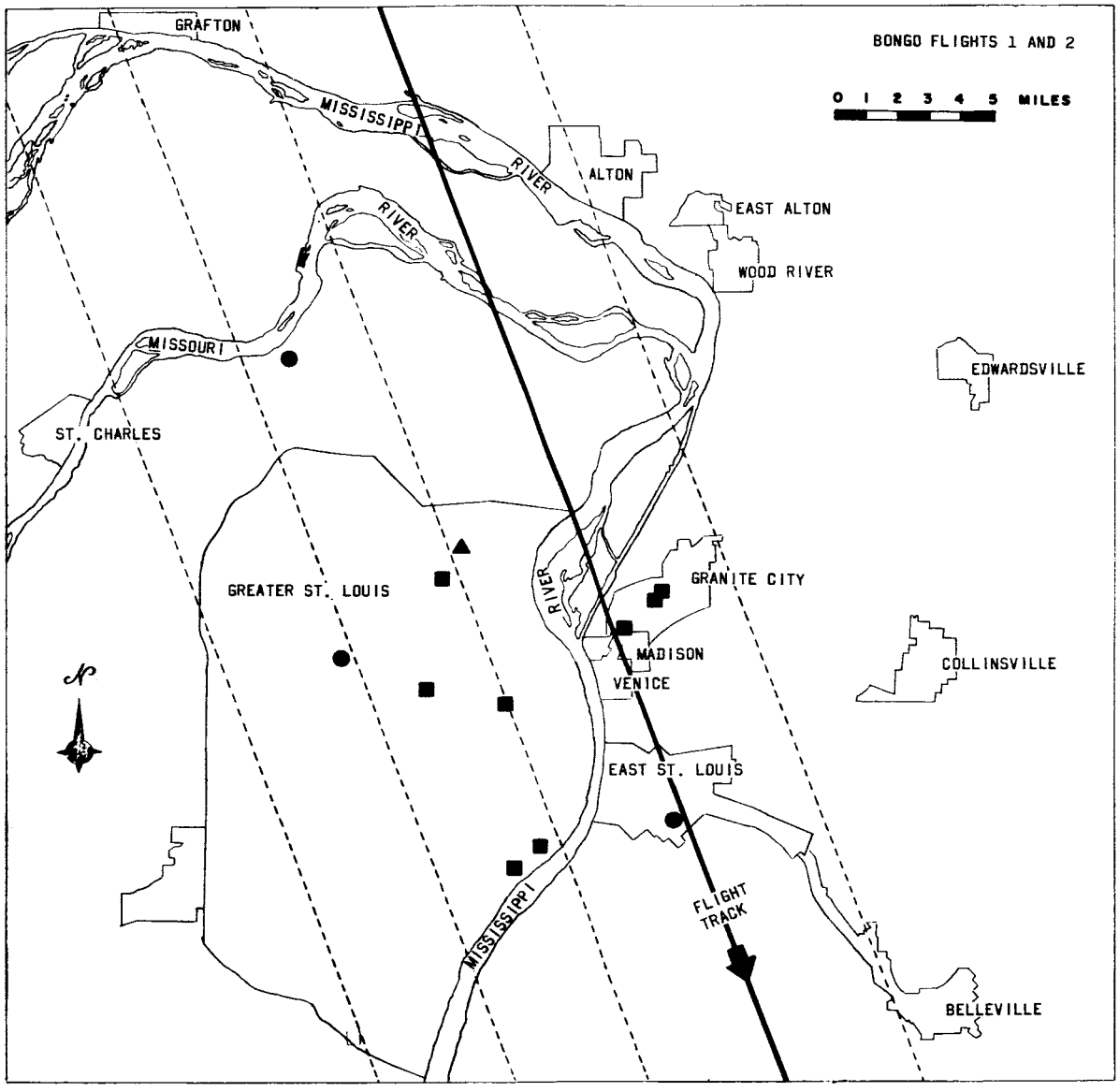


FIGURE NO. 11

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
1	6 NOV. 61	2304 CST	F-106	41,000	2.0
2	6 NOV. 61	2316 CST	F-106	41,000	2.0

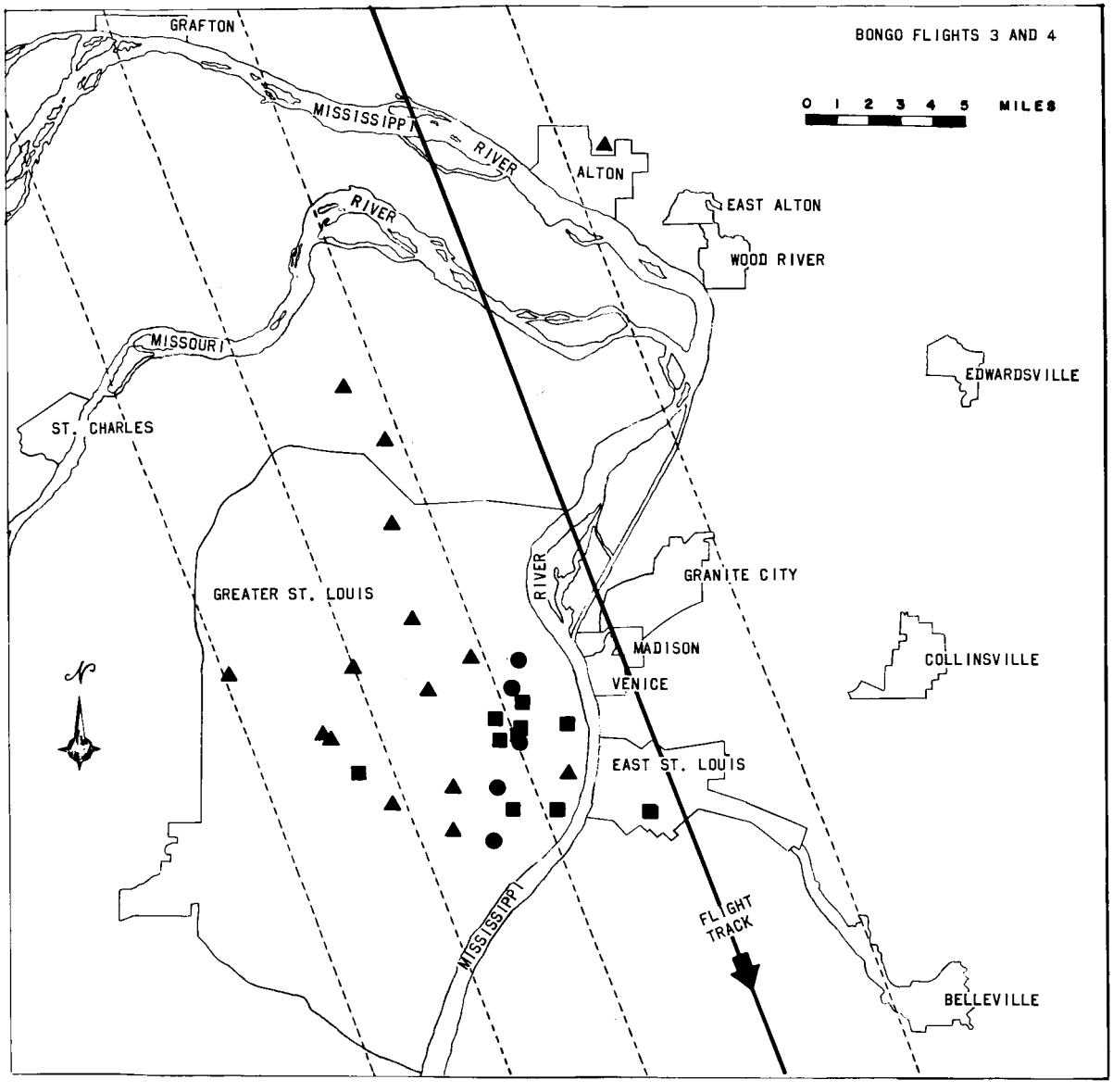


LEGEND:

- ● – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED LEGITIMATE
- ■ – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ – U.S. AIR FORCE INVESTIGATION

FIGURE NO. 12

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
3	8 NOV. 61	1105 CST	B-58	41,000	1.5
4	8 NOV. 61	1128 CST	B-58	41,000	1.5

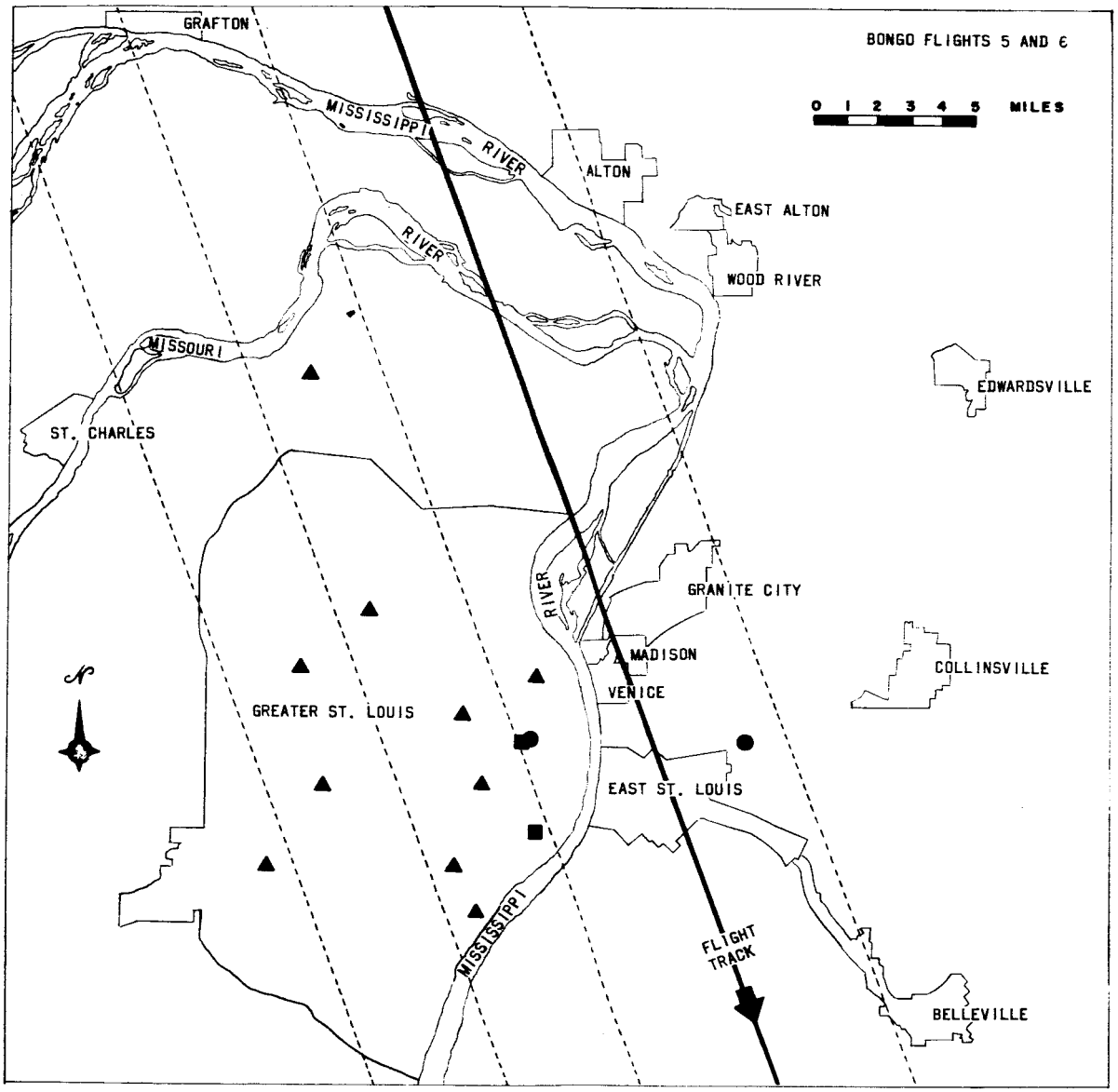


LEGEND:

- ● — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED LEGITIMATE
- ■ — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ — U.S. AIR FORCE INVESTIGATION

FIGURE NO. 13

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
5	9 NOV. 61	1258 CST	F-106	41,000	2.0
6	9 NOV. 61	1313 CST	F-106	41,000	2.0

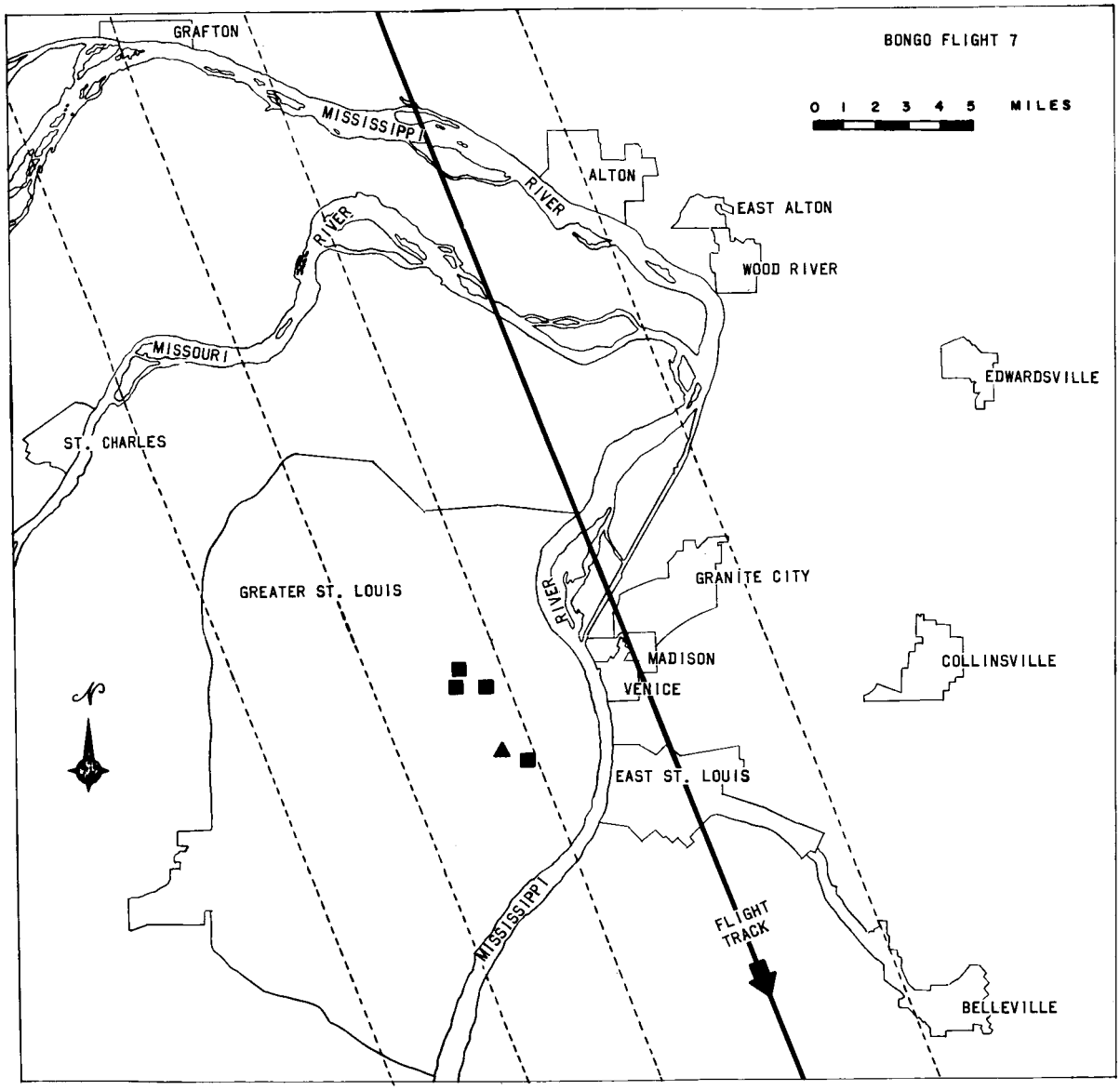


LEGEND:

- ● – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ – U.S. AIR FORCE INVESTIGATION

FIGURE NO. 14

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
7	10 NOV. 61	1759 CST	F-106	41,000	2.0

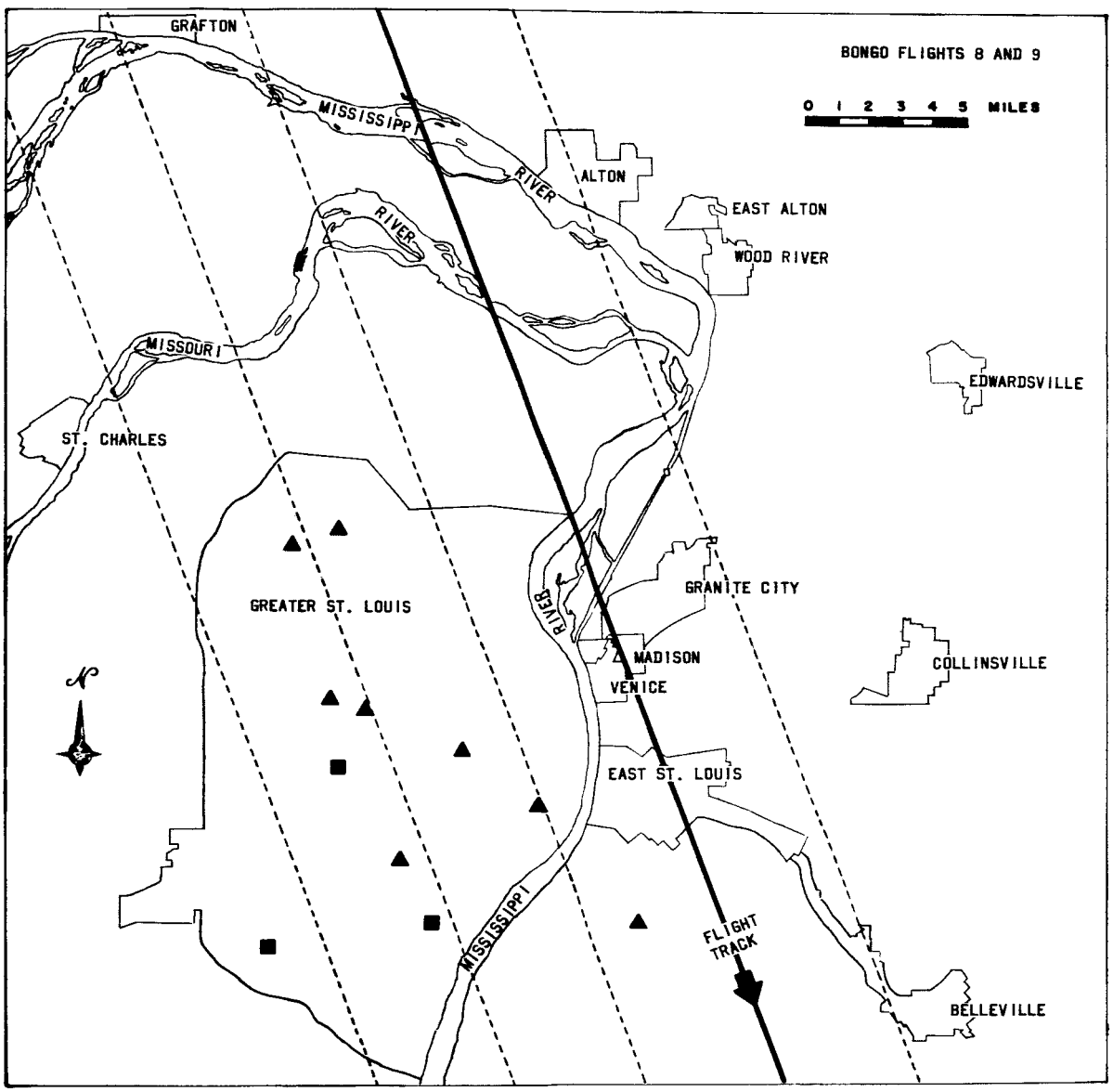


LEGEND:

- ● – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ – U.S. AIR FORCE INVESTIGATION

FIGURE NO. 15

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
8	11 NOV 61	2427 CST	B-58	41,000	1.5
9	11 NOV. 61	2450 CST	B-58	41,000	1.5

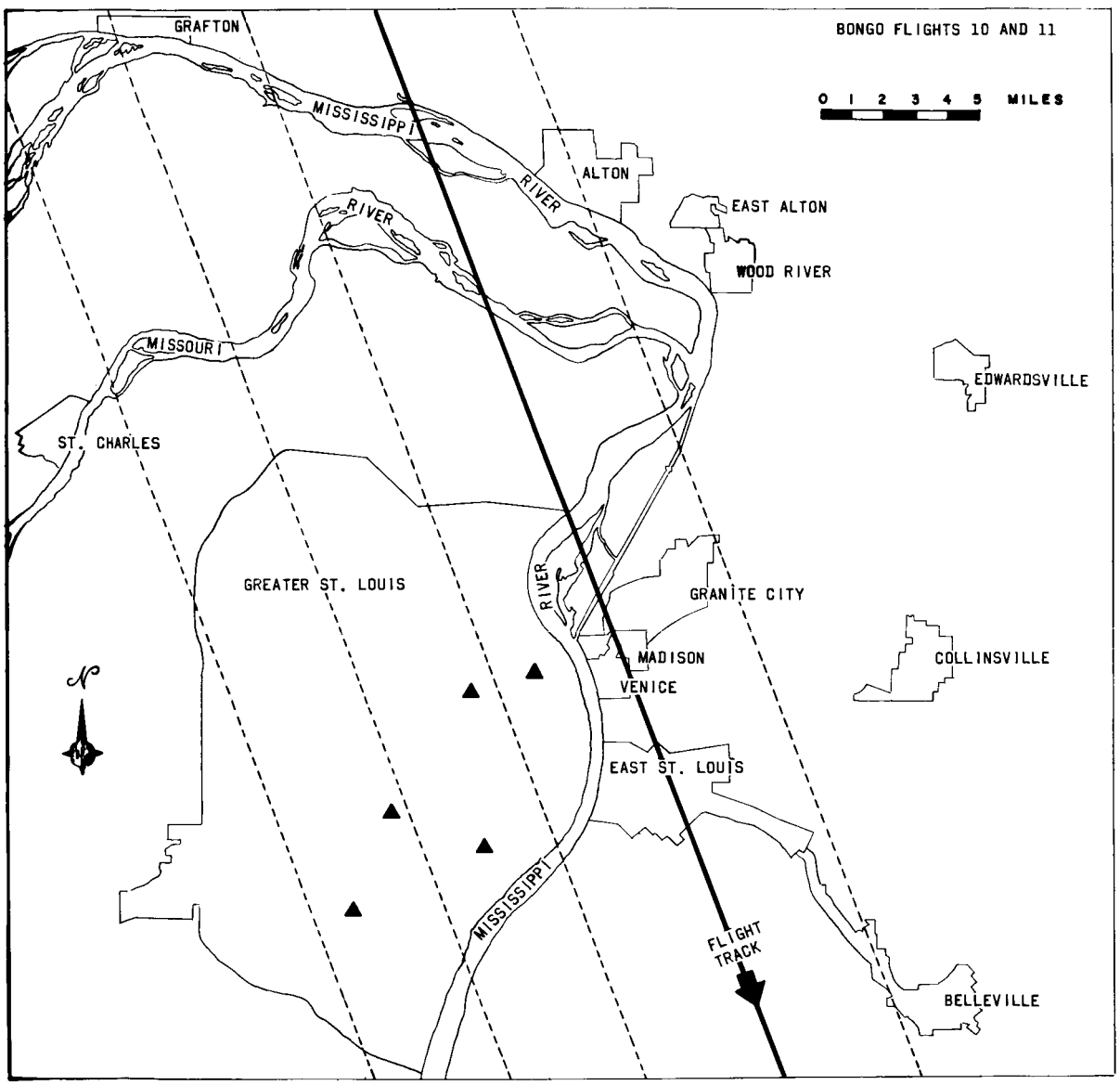


LEGEND:

- ● CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ U S AIR FORCE INVESTIGATION

FIGURE NO. 16

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
10	12 NOV. 61	0501 CST	F-106	41,000	2.0
11	12 NOV. 61	0518 CST	F-106	41,000	2.0

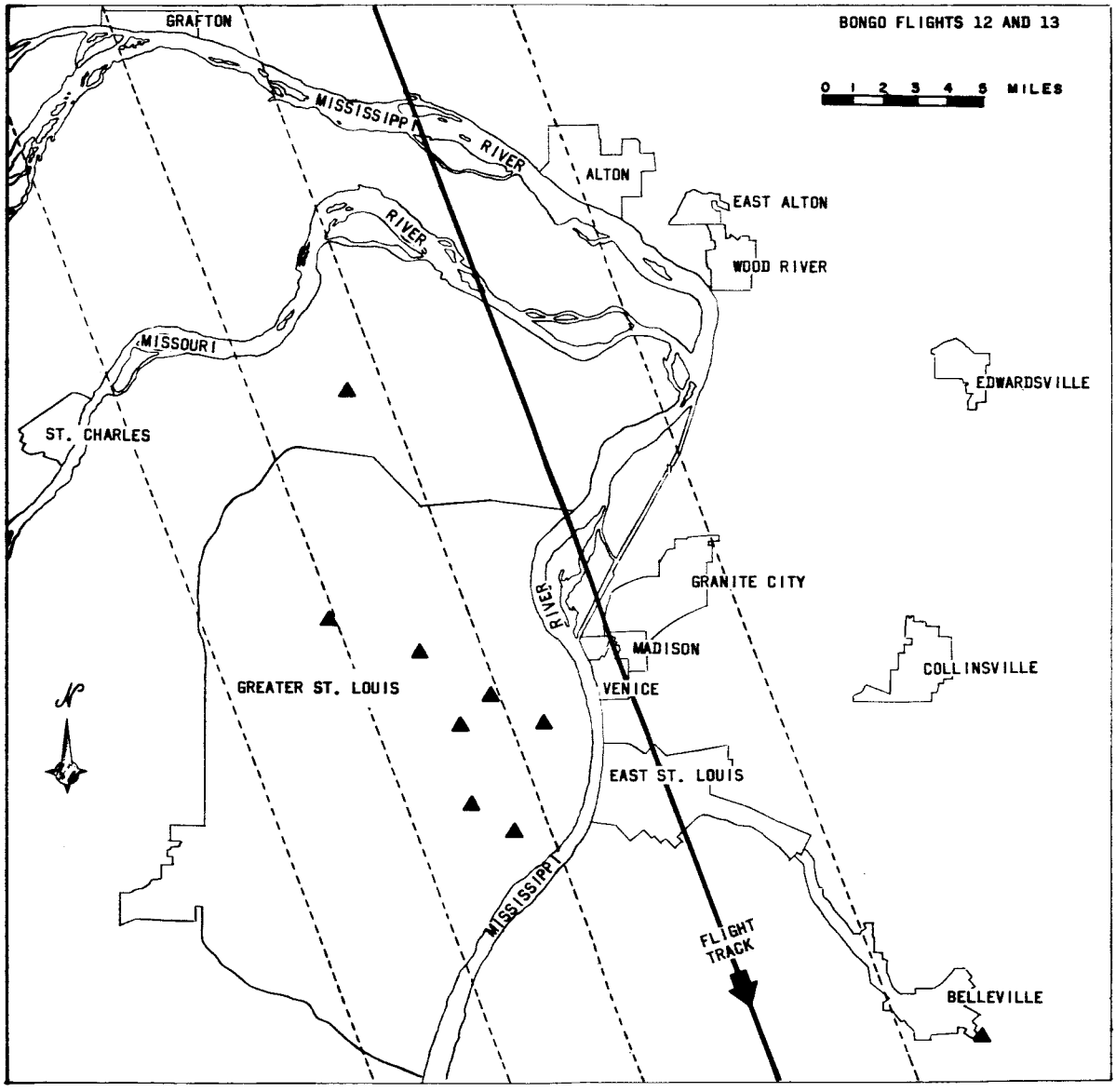


LEGEND:

- ● — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ — U.S. AIR FORCE INVESTIGATION

FIGURE NO. 17

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
12	12 NOV. 61	1016 CST	B-58	41,000	1.5
13	12 NOV 61	1041 CST	B-58	41,000	1.5

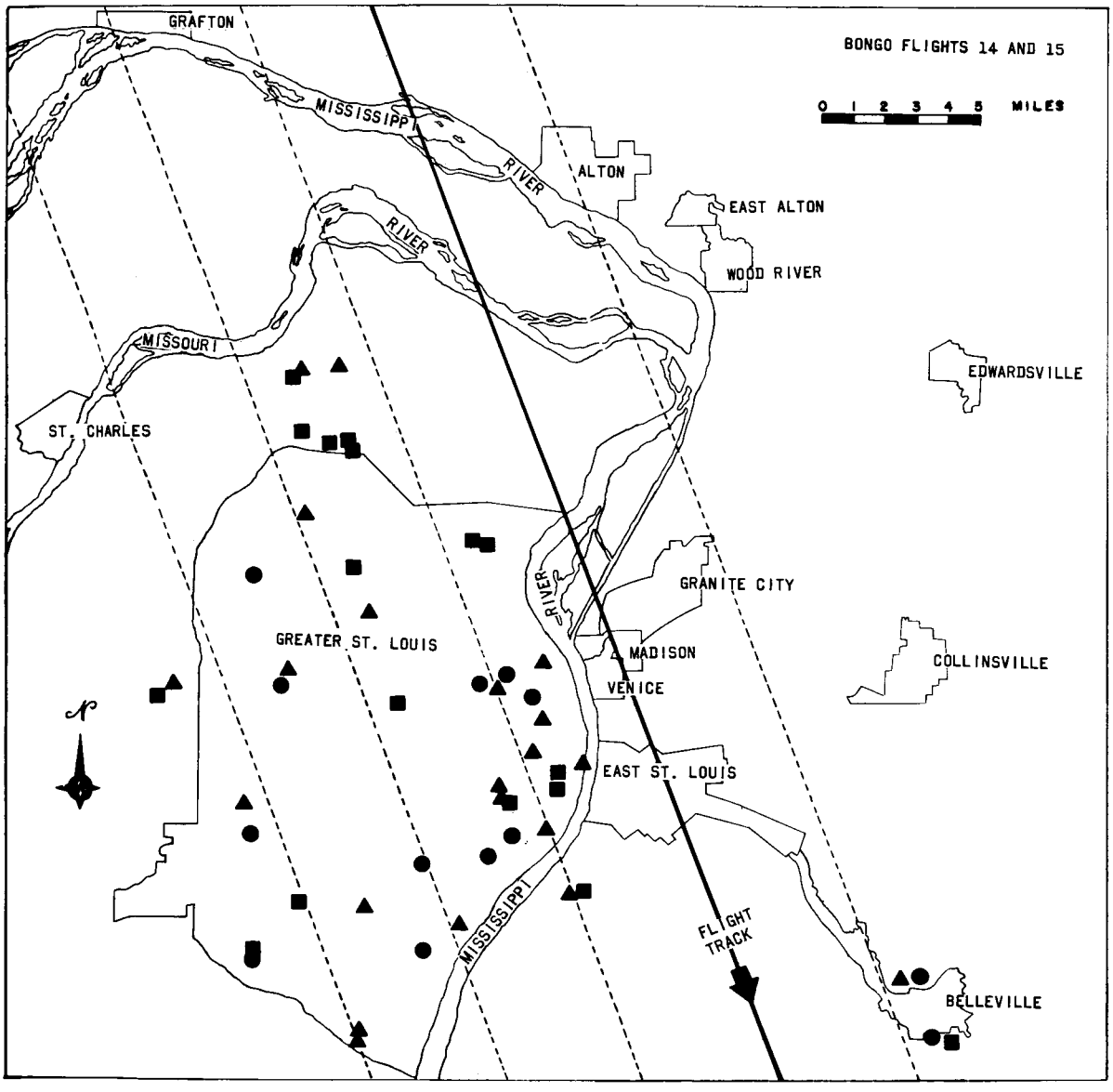


LEGEND:

- ● — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ — U.S. AIR FORCE INVESTIGATION

FIGURE NO. 18

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT.	MACH NO.
14	3 JAN. 62	2207 CST	B-58	35,000	1.5
15	3 JAN. 62	2231 CST	B-58	35,000	1.5

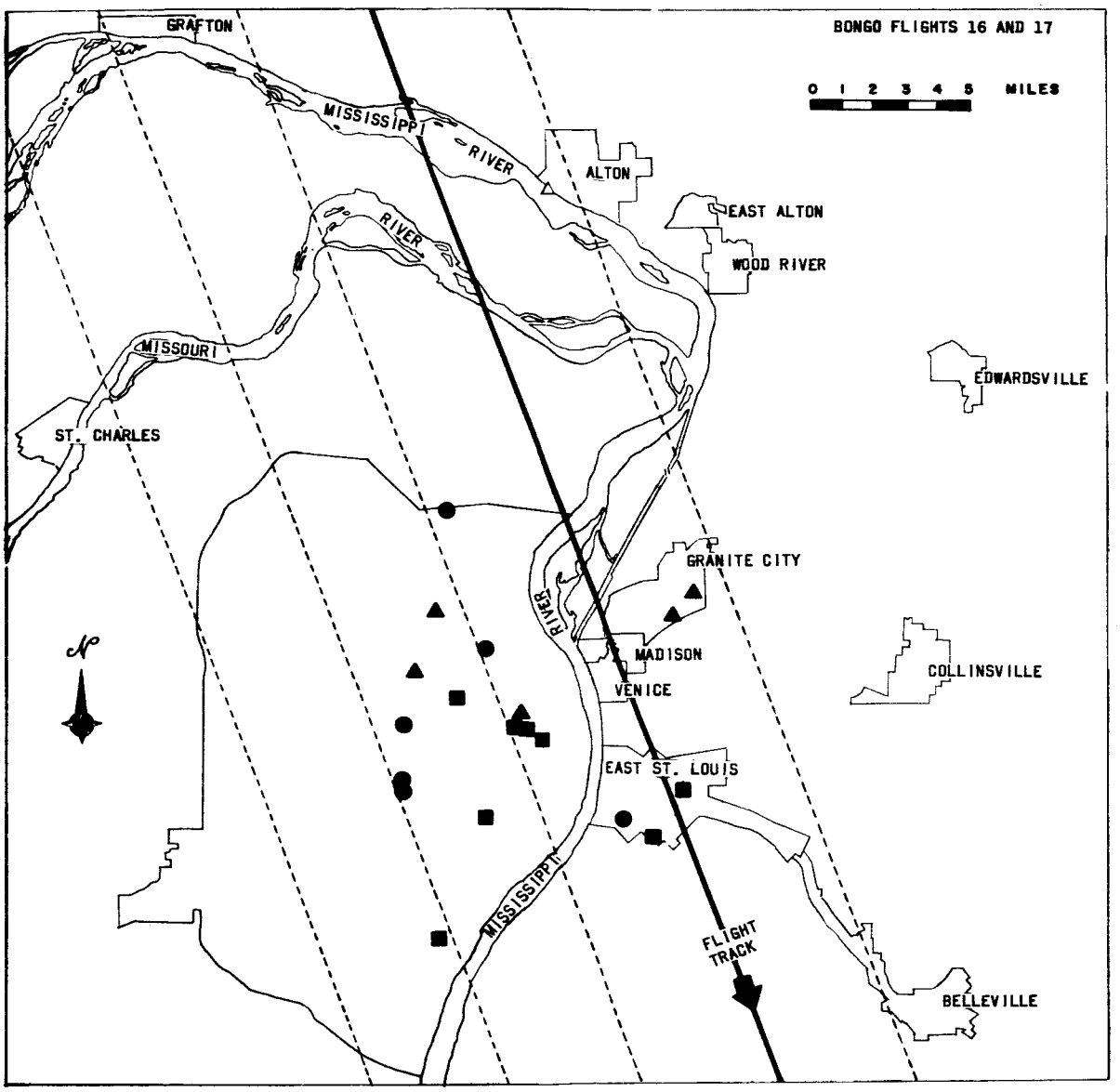


LEGEND:

- ● — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ — U.S. AIR FORCE INVESTIGATION

FIGURE NO. 19

FLIGHT NO.	DATE	TIME OF DAY	AIRCRAFT TYPE	ALTITUDE FT	MACH NO.
16	6 JAN 62	2209 CST	B-58	31,000	1.5
17	6 JAN 62	2228 CST	B-58	31,000	1.5



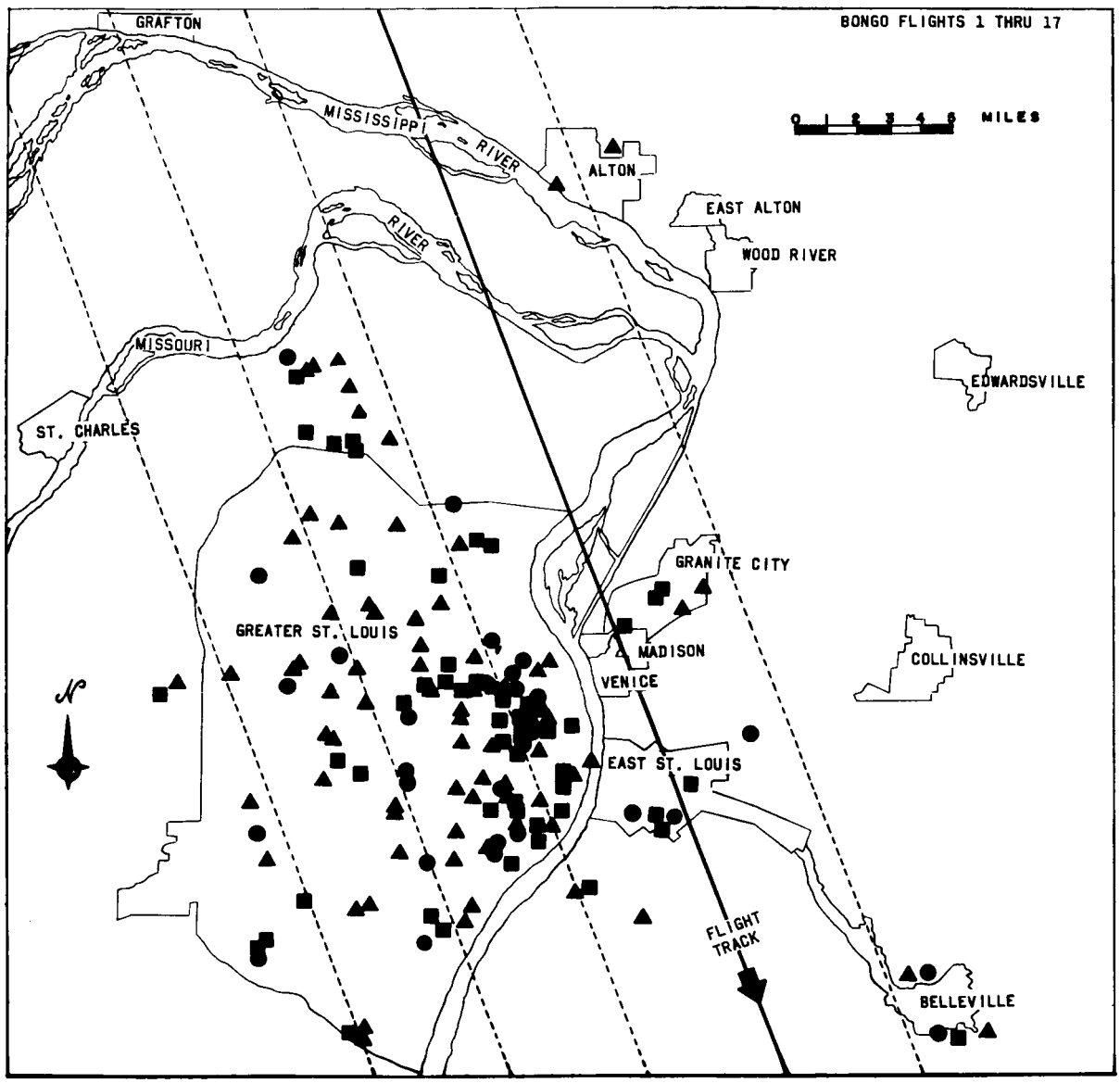
LEGEND:

● — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID

■ — CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL

▲ — U.S. AIR FORCE INVESTIGATION

FIGURE NO. 20



LEGEND

- ● – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED VALID
- ■ – CLARK, BUHR AND NEXSEN INVESTIGATION CONSIDERED DOUBTFUL
- ▲ – U.S. AIR FORCE INVESTIGATION

SECTION IV. DISCUSSION OF RESULTS

The results of the investigations of the sonic boom test flights and conferences with cognizant and interested parties have yielded several pertinent observations which are discussed briefly hereinafter.

A. From the field investigations and analyses, it is apparent that the reported damage normally occurs at stress points within a structure. Built-in stresses due to drying out of green lumber, hydration of cementious materials, and poor quality of workmanship create a potential failure of building materials. This potential exists in varying degrees in all structures, and failure can be triggered at any time. The overpressure of a sonic boom has the capability of this triggering action, as has passing vehicular traffic, thunder storms, heavy falling objects, and average household operations. Types of damage are specifically analyzed as follows:

1. Plaster.

The overpressures from the scheduled supersonic test flights described herein were not of a sufficient magnitude to cause damage to sound plaster areas. It is conceded that the experienced overpressures have the capability of triggering cracking or complete failure at a stressed portion of plaster and/or causing an existing crack to become more extensive. Also, portions of plaster that are weakened by wetting or improper installation, or portions where the lathe has deteriorated were observed to have fallen. This condition possibly could have been triggered by a person walking on the floor above the weak portion of plaster. Generally, where fallen plaster was observed, there were judged to be other contributing factors and, therefore, the damage was considered to be in the doubtful category. Plaster cracking was found in some cases where no contributing factors were judged to exist and thus the damage was considered to be valid or possibly valid.

2. Glass. (Windows, show windows, and storm windows.)

The overpressures from the scheduled supersonic test flights described herein were not of a sufficient magnitude to cause good quality, properly installed glass to break. It is conceded that overpressures have the capability of triggering cracking or breaking of glass that was stressed by improper installation, building settlement, previous damage or poor quality. Often glass cracks and breakage were judged to be associated with stress concentrations. Such stress concentrations may have been improper installation of glaziers points, glazing beads, faulty puttying, or to a flaw in the glass itself. A window set with no provision for flexing is more likely to crack than a window set in mastic which can deflect with the overpressure and thus not experience the stresses that a rigidly installed window would.

In some instances the structures investigated had an inner window cracked, whereas the storm window was not damaged. The sonic boom overpressure possibly caused the storm window to deflect, compressing the air in the space between the window and storm window to transmit the impact force to the inner window. The inner window, which is generally set more rigid than the storm window, and is not as flexible, could conceivably crack.

3. Furnishings.

In several complaints persons claimed that the sonic boom had caused damage to movable furnishings in their homes. Some persons claimed broken vases, fallen pictures, and fallen wall racks. In observing the above claimed damage, it was noticed that in most cases the fallen objects were insecurely attached to the wall. Any jolt or jar caused by persons in the immediate area of the fallen object could have caused the objects to fall. Objects which fell from shelves or window sills were obviously placed very close to the edge of the shelve or sill. Again, any jolt or jar made in the immediate area could cause the objects to fall.

4. Cracked Water Closets.

On observing several cracked water closets, it is our opinion that the sonic boom had no effect on the cracking of these objects.

5. Appliances.

The appliances that were claimed to be damaged as a result of test flight sonic booms were television sets and hot water heater thermostats.

On several occasions television sets were claimed to have failed as a result of a sonic boom. Upon investigating, it was learned that antenna, both "rabbit ears" and roof top type, had fallen from their normal position.

The thermostats on the hot water heaters failing could not be attributed to sonic booms.

6. Structural.

Since the design of walls and roofs of buildings are based on building code requirements requiring capability of resisting a minimum of 20 pounds per square foot, wind load, and the test flight overpressures were relatively small (under 3 psf), it is improbable that any structural damage to buildings that were properly constructed and well maintained was a result of sonic booms. The overpressures

could possibly have triggered cracking at a stressed condition in a structure and/or caused an existing crack to open up or grow longer.

B. Representatives of Clark, Buhr and Nexsen observed effects of sonic boom at approximately ground zero located at a likely spot in a new supermarket parking lot. The store had six large show windows of 1/4-inch thick plate glass set in aluminum frames. Window size was approximately 9 feet by 12 feet each. These windows deflected with the wind which did not exceed 20 mph and very noticeably deflected with automotive and truck traffic from the street approximately 150 feet away.

Representatives of Clark, Buhr and Nexsen observed the contrails of approaching aircraft which passed almost directly overhead. The sonic boom overpressure caused the show windows to deflect in unison, and they reverberated for approximately 3 seconds. It was interesting to observe, however, that the visible deflection did not exceed by very much the deflection caused by trucks on the highway.

C. It is the opinion of the investigators that the public information policy of the Air Force caused a high percentage of complaints. In the area around Norfolk, Virginia, booms occur with somewhat less frequency than in the St.Louis area, but only 5 complaints have been reported to the Fifth Naval District.

This indicates that the publicity by the Air Force caused an unusual number of complaints to be reported. This also allows persons who want to report doubtful claims to have an established basis for Government responsibility.

Some persons reported damage with no basis of sonic boom causation. Other persons reported damage and had no intention of making a claim. Had the publicity not been stressed, a large portion of the persons would not have complained.

D. As a result of at least 76 supersonic flights (including Air Force training missions and the special flights of these studies) experienced during a six month period in the greater St. Louis area of about three million people, approximately 2300 complaints have been registered. The percentage of complaints per capita are less than one tenth of one percent.

SECTION V. CONCLUSIONS

After research, field investigations, consultations, interviews, and conferences with cognizant Government and civilian agencies and individuals, the following conclusions have been drawn based on the opinions of the trained and impartial architect and engineer investigators:

A. Sonic boom overpressures generated by aircraft operating at the speed and altitude used for the test flights described herein are not of sufficient magnitude to cause structural damage to well constructed and well maintained buildings. Building components such as glass, plaster, etc., that tend to develop concentrations of internal stresses are subject to limited damage caused by sonic boom triggering cracking of stressed areas.

B. Poorly constructed and poorly maintained structures, and structures experiencing deterioration due to age are subject to greater amounts of damage.

C. Complaints of plaster and glass damage occurred most frequently both during the test flights and in cases on file in Air Force centers handling complaints.

D. Sonic boom damage complaints can be expected to be more numerous closer to the aircraft flight track and to diminish with increase of distance from the track. This will hold true if the population density is approximately evenly distributed, and the condition of the buildings approximately the same.

E. The test flight results indicate that about 90 percent of all complaints in the greater St. Louis area occurred within a corridor of twelve miles on each side of the aircraft flight track.

F. The manner in which the area residents have been acquainted with sonic boom causation, its capability to induce damage, and the responsibility therefor will have a bearing on the number of complaints and claims to be expected.

APPENDIX

SEISMOGRAPH DISCUSSION

From seismograph recordings taken at the time of the flights, sonic booms could not be detected by instruments situated at St. Louis University Technical Institute. The recordings showed only background noise, quarry blasts, and earthquakes.

In an explanation of the recordings to a representative of Clark, Buhr and Nexsen from personnel at St. Louis University, it was pointed out that the reason sonic booms could not be recorded by this seismograph was due to two factors, one being the sensitiveness of the instrument being too low for the high frequency booms, and the other being that the source was removed from the earth. Although nuclear explosives in the atmosphere can be detected on the seismograph, this is due to the extremely large magnitude of the explosion. Sonic booms have also been reported, but only on more sensitive instruments than the one at St. Louis University.

Quarry blasts in some cases appear very close to sonic boom times, but persons experienced in reading the data pointed out that this deviation from the normal has a definite signature which conforms to other quarry blasts.

As pointed out by personnel at St. Louis University, quarry blasts are known to cause some structural damage in the vicinity of the quarry blast.